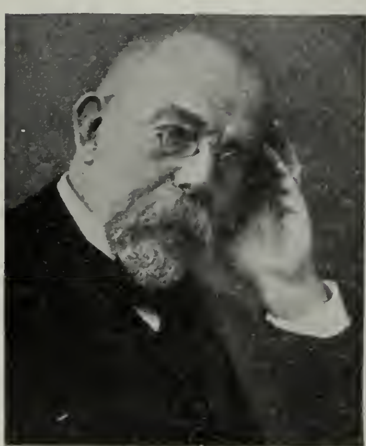
Miss Dorothy Roberta Johnson

Antonj van Leeuwenhoek (1632–1723).

Edward Jenner (1749–1823).

Louis Pasteur (1822–95).

Lord Lister (1827–1912).



Robert Koch (1843–1910). (Courtesy of Captain Henry J. Nichols, U. S. Army.)

Paul Ehrlich (1854–1915). (From Bolduan "Public Health and Hygiene.")

BACTERIOLOGY
FOR NURSES

By

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PREFACE TO THE FOURTH EDITION

THE present edition has been practically rewritten throughout in order to bring it up to date. Much new material has been included, especially in regard to immunity, allergy, disinfectants, ultramicroscopic viruses, filterable forms of bacteria, dissociation, yeasts and molds, anaërobes and anaërobic technic, undulant fever, and tuberculosis. Many new illustrations have been added. The arrangement of the material has been somewhat modified, and the demands of the Standard Curriculum have been taken into consideration.

The text-book is, in the first place, the foundation for the laboratory work, which is the most important part of the course in bacteriology. In the second place, the text-book systematizes and supplements the actual contact with materials which the student gets in the laboratory, and it should also point out the connections of bacteriology with other fields of knowledge and open up new vistas to thought and imagination. Finally, during the course and later, it serves a useful purpose as a source of reference.

The fundamental well-established principles of bacteriology have been presented, and prolonged discussions of new theories and complicated procedures have been omitted. Nevertheless, the authors have tried to lead the student to see bacteriology as a constantly changing and expanding field of knowledge, to which contributions are made from many sources.

The presentation of the material has been kept as untechnical as possible. The use of some technical terms is not wholly undesirable, however, provided that the meaning is made clear either in the text or the glossary. Sooner or later the nurse is confronted with technical terms, and it is as well she should become familiar with the common ones early in her course.

Detailed descriptions of laboratory procedures are not given. Too much detail is confusing and is of little practical value to the nurse. If more complete information on certain points is desired, it can always be obtained from medical text-books of bacteriology. Not all the material in the book will be used by every instructor, and it is inevitable also, that some teachers will desire material which is not included. The material which is given has been so arranged that the instructor may select that which is needed.

The section on experiments and demonstrations is intended to be suggestive to the instructor. The exercises may, of course, be made more elementary or more advanced, or otherwise modified to meet the needs of the students. A number of the experiments have been adapted from the course in bacteriology for nurses given at Simmons College, others from the course given at the Johns Hopkins School of Nursing. For class purposes the instructor should make use of cultures and other material which come into the hospital laboratory and should explain their clinical bearings. To see both the patient and the culture helps the student to integrate her ward- and classwork and makes bacteriology of immediate and practical interest to her. Equally important is the emphasis

on the applications of bacteriological principles and technic to many nursing procedures, which should be pointed out at every opportunity during the course. The short excursions into pathology, clinical medicine, and public health are given to indicate the relation of bacteriology to these fields, to give it greater vividness, and to serve as an introduction to the nurse's later study of these subjects. Although of course this book is complete in itself, it is intended to form an integrated whole with Morse's Public Health and Social Questions for Nurses.

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Baltimore, Maryland.
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CONTENTS

SECTION I. GENERAL BACTERIOLOGY

SECTION II. SPECIAL BACTERIOLOGY

LIST OF ILLUSTRATIONS

Bacteriology for Nurses

SECTION I

General Bacteriology

CHAPTER I

INTRODUCTION

Biology—Protoplasm—The cell—Single-celled organisms: metabolism: multiplication—Tissues and organs—Enzymes—The blood in relation to bacteriology.

Biology.—Before taking up a study of the bacteria, it may be well, as a background, to discuss with exceeding briefness the nature of living things in general. This will be chiefly as a review, since the student is probably familiar, from her previous work, with most of the conceptions; but it will help her to see the bacteria in their place among other living things. Although the nature of life is an absolute mystery, we can study the form, structure, and activities of living things. This study constitutes the science of *Biology*, and *Bacteriology is one branch of Biology.*

Protoplasm (from two Greek words: proto, *first*, and plasm, *substance*).—*All living matter is composed of a foundation substance called protoplasm.* This substance is in general watery, transparent, usually colorless, and very much like raw white of egg. When analysed chemically, it is found to consist largely of carbon,

oxygen, hydrogen, and nitrogen. Many other elements, such as sulphur, phosphorus, and various metals may also be present. In what way these elements are combined to form protoplasm, is unknown. *Nitrogen must, however, always be present.* This will be discussed later when we consider the relationships between different forms of living creatures. Here it is sufficient to say that nitrogen, in the form in which it exists in the air, cannot be used by most living creatures until it is combined chemically with some other substance—usually oxygen. It is the function of certain bacteria to bring about this combination.

The Cell.—It might be imagined that if all living things were composed of a watery substance, they would soon collapse, drain away, or dry up. How do living things maintain their shape and continue to keep from being dissolved? It was discovered in 1838 by Schleiden and Schwann, two German scientists, that the protoplasm of all living things is contained in tiny subdivisions or chambers, which are called *cells*. Most cells are extremely minute, and many millions of them are required to form so large a creature as a tadpole. Cells, however, vary greatly in size, and some are several inches in diameter. All eggs are single cells. An ostrich egg is certainly far from microscopic. Some cells, such as nerve cells, may have portions a foot or more in length, although these filaments may be of microscopic fineness.

The protoplasm of each cell is differentiated into at least two special portions (Fig. 1). First, part of the protoplasm is thicker and more membrane-like at the outer boundary and thus forms a retaining *wall* which holds the cell contents. Another portion of the proto-

plasm is condensed into a definite globule, usually situated near the center, which is called the *nucleus*. It appears to be the essential part of the cell, since without it the cell soon dies. On the other hand, the nucleus may live by itself for some time. Indeed,

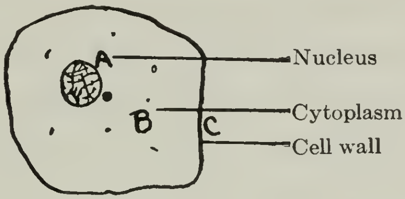

Fig. 1.—Diagram of a cell, showing essential parts. Many cells are much more complicated than this one.

there are some cells, for example spermatozoa, which appear to consist almost entirely of nuclear material.

Single-celled Organisms.—Some cells live singly, unassociated with other cells. Bacteria belong to this group. Some of these unicellular organisms live deep in the waters of the sea; others, in pools of stagnant water; still others can exist only in animal blood or serum. The entire life work of such unicellular plants (or animals, as the case may be) consists of feeding, excreting waste products, and multiplying.

Metabolism of Single-celled Organisms.—Since these organisms have only a cell membrane, a nucleus, and the bit of remaining protoplasm spoken of as *cytoplasm* (cyto: Greek for *cell;* plasm: Greek for *substance*), it may seem strange that they are able to do even as much as eat and breathe. In the first place, with the exception of only one or two classes of cells, their food must be in solution, that is, dissolved in water. In this form, when the cells are bathed in a solution such as blood, beef broth, or sea water, the substances which they use as food simply soak into them through the

cell wall. Waste products in turn soak outward. If the volume of fluid in which the cells are suspended is small, as in a test tube or a tiny pool, the cells are soon surrounded by a mixture of food substances and waste products, all in solution. The food may then give out, or the accumulation of waste products may result in stopping the growth of the cells.

The cell wall seems to be permeable to just the right substances. It allows only waste products and certain other substances to pass outward, and only food substances to pass inward. Oxygen also, small amounts of which are always found dissolved in water, usually passes through the membrane. The process is entirely passive. The cell simply absorbs its food. The processes by which the waste products and other substances pass outward are called *diffusion* and *osmosis*. Different cells secrete by diffusion or osmosis, different substances in addition to their waste products.

Multiplication.—The division of cells in general (for example, those making up the tissues of plants and animals) takes place by a complicated process of division of the nucleus, called *mitosis*,[1] with which the student is probably somewhat familiar from her work in anatomy and physiology. It has not been proved that bacterial cells divide by mitosis. In fact, at the present time the whole subject of the method of reproduction of bacteria is a matter of intense interest and controversy. It will be discussed in the next chapter.

Some single-celled organisms divide by processes much simpler than mitosis. Some appear merely to break apart in the middle, forming two similar cells.

[1] For the bearings of this on heredity, see Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

Yeast cells (Fig. 103), as will be discussed later, multiply by *budding, i. e.*, by pinching off a part of the cell to form a "daughter cell."

In any case, all cells must take nourishment, excrete waste matter, and multiply. These three essential processes take place in the unicellular forms as well as in the cells of large multicellular organisms. All that is necessary for the unicellular forms is to find suitable fluids in which to live. In nature there is much fluid matter where unicellular organisms may thrive—for example, rivers, sewage, decaying animal and plant tissues. The cells of multicellular organisms are constantly bathed in special fluids. In animals this is the blood and lymph; in plants, the sap.

Tissues and Organs.—Many cells are grouped together in ways mutually advantageous. In some cases, the relationship is relatively simple, as when certain bacteria live on the roots of clover plants (Fig. 9), and help the plant to obtain nitrogen from the air. In other instances, the relationships between the cells involve extremely complex reactions, as in the animal body. The cells of the animal body all have a common origin in the fertilized egg cell. During embryonic life, however, they develop into various specialized types. A group of cells of the same kind, which have the same shape, constitution, and function in the body, is called a *tissue*. Masses of specialized tissues are grouped together to form structures which perform a definite function in the body, *i. e.*, organs. The essential cells of an organ are held in place by other less specialized cells, which form *connective tissue*.

Enzymes.—Cells often have the power of changing solid food substances into liquids and thus availing

themselves of additional sources of nourishment. They do this by means of certain special secretions called *enzymes*. The nature of these is rather obscure, but we know that they exist and that they can bring about the most remarkable changes in a great variety of substances. There are enzymes which can so change gelatin that it becomes permanently liquid and will no longer "set." Others change sugar into alcohol and carbon dioxide. Common baker's yeast gives off an enzyme which does this and the process is used in making wine and bread. The cells which line our stomachs and intestines produce digestive enzymes. There are thousands of different enzymes. Not all cells, of course, produce all kinds. Most cells produce only one, two or three. Some of the enzymes, or enzyme-like substances, which certain bacteria produce are very poisonous (or *toxic*, as it is called) and produce disease.

Bacteria which produce disease in any manner are spoken of as *pathogenic* (patho = *disease;* genic = *producing*). Not all pathogenic bacteria, however, are so because of their enzyme or toxin secretion. Some are pathogenic because they are composed of protoplasm which is, in itself, poisonous to us, very much as some toadstools are composed of extremely poisonous matter.

The Blood in Relation to Bacteriology.—Before leaving the discussion of cells and tissues in general, it may be well to review very briefly the composition of the blood, particularly in its relation to bacteriology, as we shall have much to say of it later. The blood serves every cell in the body, carries its food to it, removes its waste products, and may bring destruction to the cells, if bacteria or their poisons invade the body.

On the other hand, the blood contains substances to help the cells combat disease.

Blood consists of four essential constituents. First, the fluid portion or *plasma*, a yellowish, transparent fluid, consisting of a solution of proteins and other soluble substances, food for the body cells and waste products excreted from the cells. The plasma is the

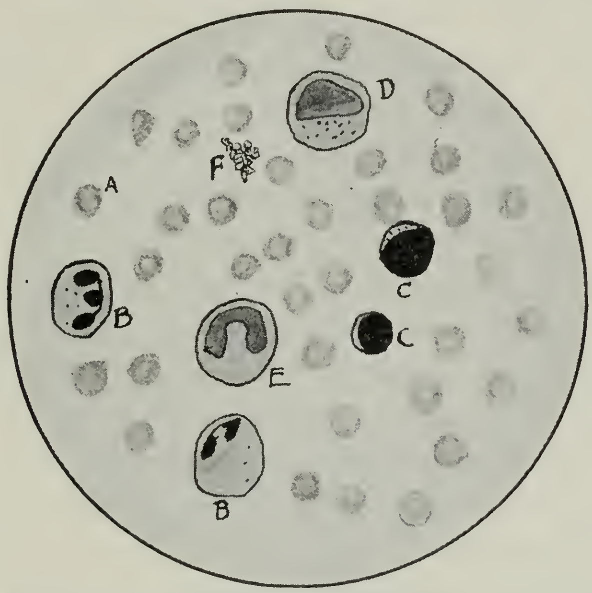

Fig. 2.—Stained smear of normal human blood showing different kinds of corpuscles. A, Red corpuscles; B, white corpuscles (polymorphonucleated leukocytes); C, small lymphocytes (another kind of leukocyte); D and E, other kinds of leukocytes (large lymphocytes). F, Blood platelets. Magnified 600 times.

vehicle for circulating bacteria, their toxins, and the substances which the body cells produce in response to bacterial stimulation.

The *red corpuscles*, or erythrocytes (erythro = *red;* cyte = *cell*), are cells which are formed in the spleen, liver and bone-marrow and float in the plasma. The red color of the blood is due to the hemoglobin which they contain. They have no nucleus and hence

are probably not very long-lived but are constantly being replaced. They carry oxygen from the lungs to all parts of the body, and thus the innermost cells of the body breathe. They number about 15,000,000 to the drop (5,000,000 per cubic millimeter).

When the red cells break up, the hemoglobin escapes into the surrounding fluid. This process is called *hemolysis* (hem- *blood*, and lys- to *dissolve*). Certain bacterial toxins have the power of destroying red corpuscles both in the body (producing an anemia), and in the test tube. As we shall see later, this characteristic is studied in the laboratory as one method of identifying an organism (Fig. 40).

If an animal is injected several times with the red cells of another species of animal, the serum of the injected animal acquires the power of dissolving the corpuscles of the second animal. This is an illustration of one of the most important principles in immunology, and is made use of in certain tests for disease (Fig. 28), to be described later.

The *white corpuscles* or leukocytes (leuko = *white*) are much larger and less numerous than the red cells. There are only about 7000 per cubic millimeter. They have a very important function in acting as scavengers and "policemen" in the blood. Any foreign particles, such as dead cells or bacteria, finding their way into the blood or tissues, are promptly disposed of by the white cells, which have the power of eating solid particles. As the leukocytes have the power of ameboid movement, they can flow around the particles and engulf them. (Figs. 3, 45, and 50.) The particle passes through the cell wall into the interior of the cell. It may be liquified there by digestive enzymes inside the

cell. Leukocytes are able to move out of the blood vessels and travel about through the tissues. When some undesirable particles (as bacteria in a boil) set up inflammation, the leukocytes are attracted to the spot by chemical substances in the affected tissue, and congregate there, sometimes in enormous numbers.

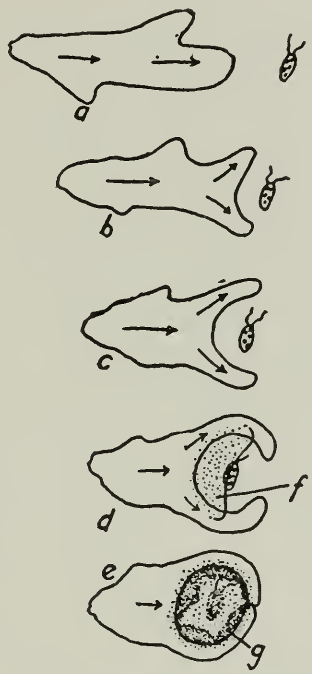

Fig. 3.—Diagrammatic representation of the stages (a–e) in the movement of an ameba, and the ingestion of food. Similar changes occur in white corpuscles as they ingest bacteria. (From Schaeffer "Ameboid Movement," Princeton University Press, Publishers.)

They endeavor to dispose of the foreign particles by eating or engulfing them. Usually many of the leukocytes die in the process. The white, creamy material in a boil or other infected spot consists largely of these dead leukocytes, dead bacteria, and some of the tissue cells and blood serum, all mixed up together. This material is called *pus*. The dead leukocytes are

called *pus cells.* The process will be discussed later on under "Inflammation."

Plasma contains the material which makes blood *clot* when it gets outside the body. Inside the body certain substances in the plasma keep the blood in fluid condition. Once the blood escapes, however, it is changed, and the clot forms. The clot is composed of fibrin. This is elastic, and as it shrinks, it pulls the red and white cells with it. The fluid portion of the blood is squeezed out of the clot and appears as a clear, pearly gray or straw-colored fluid called *serum.* Serum contains all the soluble parts of the blood. It is really the plasma deprived of its red and white cells and its fibrin. It is used widely in the study of disease and is of the greatest importance in bacteriology, as it contains the bacterial toxins and the antibacterial substances.

CHAPTER II

BACTERIA: DISTRIBUTION AND ACTIVITIES

Historical note—Bacteria: size and weight; multiplication—The work of bacteria in the outside world: putrefaction; purification of sewage and water; production of food for plants—The infectious diseases of plants—Bacteria in water; in air—The growth of bacteria in food—Distribution of bacteria in and on human beings.

Having now some idea of what the life processes of living cells are, let us turn our attention more especially to those simple, single cells, the bacteria. Bacteria are unicellular plants. They were probably among the very earliest forms of life to appear on the earth. It is probable that they helped prepare the earth for the further development of plants and animals.

Historical Note.—Bacteria, however, were not discovered until fairly recent times, for, because of their minuteness, a knowledge of their existence had to await the invention of the microscope. The first person who saw and described bacteria was *Antonj van Leeuwenhoek*, a Dutch investigator (see Frontispiece) who made one of the earliest microscopes (Fig. 4). With this crude instrument he examined water from pools, the tartar from his teeth, feces from a case of dysentery, and many other substances and fluids. He was amazed to see in all of these what he called tiny animals, round, rodlike, and spiral-shaped, some of which were in rapid motion. The drawings which he made are still in existence (Fig. 4), and prove that what he saw actually were bacteria. This discovery of

van Leeuwenhoek's in 1683 opened up a new world—that of the extremely small. The importance of his observations was not appreciated, however, and it was about a hundred and fifty years before much advance was made in the investigation of bacteria.

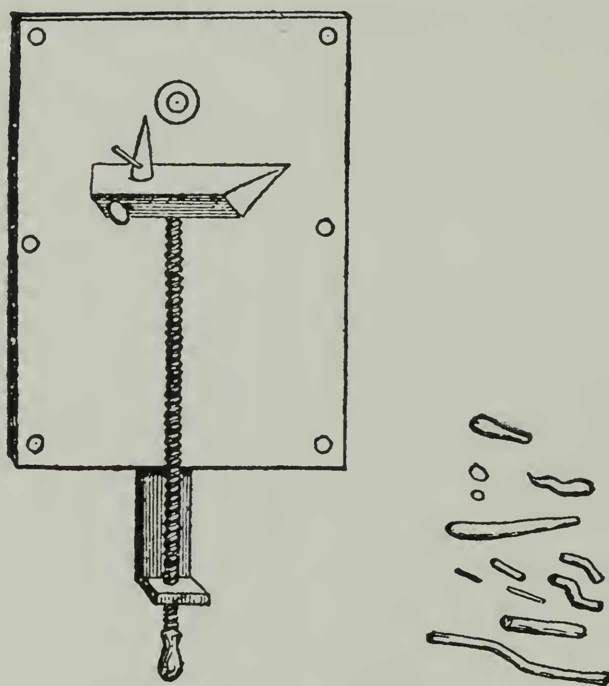

Fig. 4.—Van Leeuwenhoek's microscope (after Loeffler) and sketches of bacteria. The round lens of the microscope is set in the center of a metal plate. The object is placed on the table which is adjusted to the right focus by means of a screw. Compare with Fig. 12, and Plates I and II. (From Conn and Conn, "Bacteriology," Williams and Wilkins Co., Publishers.)

Following the discovery of bacteria, the idea gradually grew up that they were the cause of disease, but this could not be proved until methods of cultivating organisms in pure culture in the laboratory had been worked out. This was largely the work of two men: *Louis Pasteur*, a French scientist, and *Robert Koch*, a German physician. (See Frontispiece.) Shortly after

the middle of the last century Pasteur proved that fermentation and putrefaction were caused by living organisms, and about 1880 Koch introduced the general methods of cultivating bacteria in cultures which are still in use today. *Lister*, an English surgeon, applied Pasteur's discoveries to surgery even before the actual bacteria which cause infections had been discovered.

The work of Pasteur and Koch was the beginning of the science of bacteriology, and it opened up a new world to medicine. Within the fifteen years following 1880 the organisms causing the majority of infectious diseases had been discovered.

Size and Weight of Bacteria.—It is easy to see why a microscope is necessary for the discovery and study of bacteria when we realize that the largest bacteria are only about $\frac{1}{500}$ of an inch long. The common bacteria of the intestine are only about $\frac{1}{10,000}$ of an inch long. Nearly 2 billion (2,000,000,000) of medium-sized bacteria may easily be contained in a single drop of water, and about 30,000,000,000 would hardly weigh as much as a ten cent piece. Perhaps the largest patho-

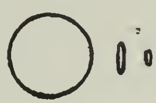

Fig. 5.—Comparative size of a human red corpuscle; the typhoid bacillus, a bacterium of average size; and the influenza bacillus, one of the smallest bacilli. (From Jordan "General Bacteriology.")

genic bacterium is the spirochete of relapsing fever (Fig. 76).

The unit of measurement for microscopic objects of any kind is the *micron* or micromillimeter, which equals $\frac{1}{1000}$ millimeter, or about $\frac{1}{25,000}$ inch (Fig. 5). It

is commonly designated by the Greek letter μ (m, pronounced mu). The nature of the light rays and the anatomy of the eye restricts the limits of clear vision to objects of a size not less than 0.1–0.2μ. By the use of sunlight in the ultramicroscope, as will be described later, objects as small as 0.004μ can be made visible. Proof exists that there are microörganisms much smaller than this, which cannot be seen even with the strongest microscopes. It is doubtful, however, whether these latter are true bacteria.

Multiplication.—Until recently, it has been considered that bacteria multiply by simple fission, or breaking in two, as described in the preceding chapter. According to this theory, there are no sexes. When a cell becomes mature, it splits in two. Each half receives half of the cell wall, half of the nucleus and half of the cytoplasm and any other special parts of the protoplasm which may be present in that particular sort of cell. The two cells are called daughter cells. They in turn mature and split, and so the process goes on as long as nitrogen-containing food is present, waste products do not accumulate too much, and there are enough oxygen and water and other necessary materials.

Recently evidence has been advanced which indicates that the process of multiplication of bacteria is not as simple as it appears. Some bacteriologists describe sexual forms and believe that many species of bacteria undergo a rather complicated series of changes, which may involve the simple process already described and, in addition, the formation of branching forms, with spore-like bodies, the formation of extremely minute forms which cannot be seen even with the most powerful microscopes (filterable forms), and other curious

phenomena. These statements will acquire more meaning when we study ultramicroscopic organisms, the higher bacteria, and yeasts and molds. Our ideas concerning the life cycles of bacteria need revision, but there is as yet too little agreement among bacteriologists to warrant any definite statement at present.

Classification.—Are bacteria animals or plants? Where do they stand in relation to other forms of life? We have said at the beginning of this chapter that bacteria are single-celled plants. There is some difficulty, however, about their classification because the lower we descend in the scale of living things, the less specialized are the forms and functions of different groups, and therefore sharply defined bases for classification are lacking. Although, strictly speaking, bacteria can be classified as a whole neither in the animal nor the vegetable kingdom, they are more like the lowest forms of plants than of animals. They are classed, with yeasts and molds, in the group of the *fungi*, which are plants without roots, stems, or leaves, and devoid of chlorophyll. Mushrooms are an example of the higher type of fungi. The reasons for this classification will be apparent when we come to study the yeasts and molds.

It is possible that the bacteria are the primeval group from which in the course of evolution, both plants and animals are derived, the lowest forms of plant life splitting off from the group and developing in one direction; the lowest forms of animal life in another direction.

The Work of Bacteria in the Outside World.—Persons whose work lies constantly with disease, as doctors and nurses, are inclined to have a one-sided view of bacteria. They may think of them all as evil and as ene-

mies of human life; whereas comparatively few kinds cause disease. The greater number are harmless to man, and the work of most bacteria is good and, in fact, necessary to human life. Bacteria may, therefore, be divided into two great groups according to their activities: the harmful and the useful. The first kind, the *pathogenic*, live on or in the bodies of human beings and cause disease. The second kind have their home in the outside world and are harmless to man. These are spoken of as *saprophytic*, unless they are pathogenic for plants or animals. Out of more than two thousand known kinds of bacteria, less than one hundred injure any one.

Many of the pathogenic bacteria can live only in the body, and find the outside world cold, dry, and unfriendly, and soon die if they are cast forth into it. On the other hand, the human body is too warm and other conditions are unsuitable for those which are adapted only to life outside, so that they do not multiply there.

Before studying the disease-producing bacteria, with which medicine and public health are chiefly concerned, we should get a wider view of the activities of bacteria and their place and importance in the world. So we will take up first the useful bacteria, the work of which we see all about us.

Putrefaction.—The useful bacteria carry on a multitude of tasks in nature and bring about changes which are necessary for the existence of animals and man. One of their most important activities is the decomposition of dead animal and vegetable matter, a process which we know as *decay* or *putrefaction*.

Putrefaction is nature's way of purifying the earth. The complicated materials of the plant or the animal

body are decomposed after death into water, gases, and simple substances which plants can use for food. For instance, when a dead animal is buried in the ground, bacteria from the soil, and those already in the animal's intestine, enter the tissues and cause them to disintegrate. The gases and water which are formed pass off into the earth, and other substances which the bacteria produce from the animal's body contain combined nitrogen and are suitable food for plants. In

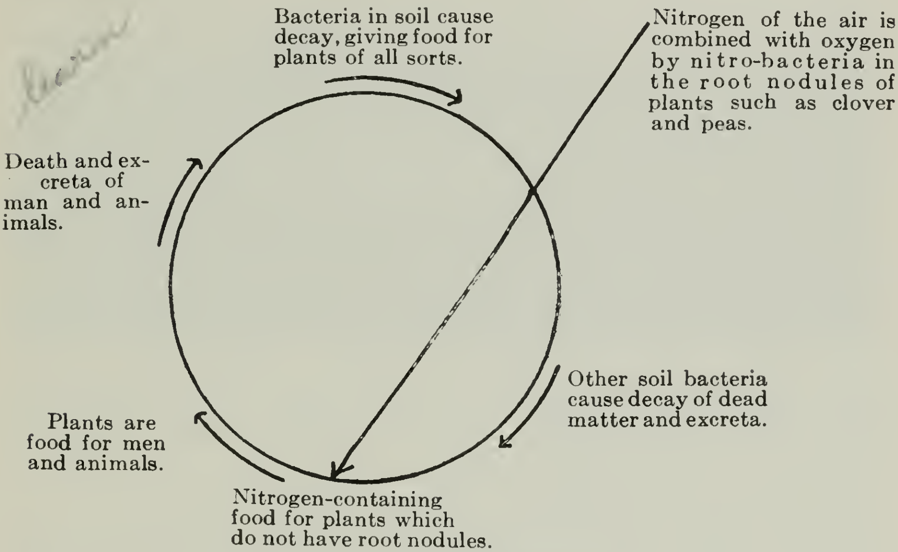

Fig. 6.—The nitrogen cycle.

this way the dead animal body disappears, and the materials of which it was made up are used over again to nourish plants. Animals use the plants for food, and after their death they in turn are changed into food for plants. It is through the work of bacteria that the accumulation of dead animal and vegetable matter is prevented and the earth kept fit for living things. Without their activity life would be impossible. This cycle of changes (Fig. 6) in which bacteria

are the connecting link between death and life, is one of the most marvelous and beautiful provisions in nature. Practically all of the changes involved in decomposition are brought about by the enzymes secreted by the bacteria.

The conditions most favorable for putrefaction are therefore those which are most suitable for the growth of bacteria. A moderately warm temperature, about that of hot summer weather, is best. Moisture is also necessary, for, as every one knows, no perfectly dry substance ever putrefies. We all know how quickly things decay or spoil in hot, damp weather. The process goes on best in the dark, and can be decreased or even stopped by sunlight.

The wastes of man and animals (feces and urine) are disposed of by bacteria in the same way as dead animal and vegetable matter. If put on or in the soil, all traces of them soon disappear. When the farmer spreads manure on land, it is changed by bacteria into substances which plants can use for growth. The soil is thus enriched and made more fertile.

Purification of Sewage and Water.[1]—Bacteria also purify sewage. People can live in large communities only when there is some way of taking care of their wastes. Great epidemics have been caused in the past by the accumulation of human excreta in cities with resultant contamination of water supplies. Some of the plagues and pestilences which we read of in history were undoubtedly due to this cause. Now the activities of bacteria are made use of in purifying sewage. The

[1] For a more extended discussion, see Chapters VIII and IX of Morse's Public Health and Social Questions: An Introductory Textbook for Nurses. Philadelphia: W. B. Saunders Company, 1932.

bacteria live on the organic substances of the sewage and turn them into harmless, inoffensive materials which are food for plants. In the privy and cesspool this work is accomplished by the soil bacteria, as the contents slowly soak into the earth. In the sewage purification plants of cities the process is controlled scientifically.

Fig. 7.—A trickling filter at Gaithersburg, Md. The picture shows a raised bed of gravel several feet thick. The sewage, which consists of about 99 per cent water, is brought to the filter in pipes and is sprayed over the surface from a number of nozzles. It trickles among the stones, which are covered with a slimy layer of bacteria. The bacteria feed on the organic material in the sewage, reducing it to simpler substances which are harmless for man and animals. The sewage is thus purified through the action of the bacteria. (Courtesy of Robert B. Morse, Chief Engineer of the Washington Suburban Sanitary Commission.)

A much used method for purifying sewage is first to strain out the larger particles by passing it through metal "screens"; then to allow it to flow very slowly through large tanks, where some of the materials in suspension settle to the bottom. It is then sprayed on the surface of large beds of gravel (Fig. 7). It trickles

slowly through these, is collected in drains under the gravel, and is finally carried away to a convenient water course. The actual chemical processes resulting in purification are accomplished by a film of bacteria which gradually grows around the gravel particles after they have been in contact with sewage for some time.

The soil bacteria also purify water in the same way as they do sewage. They take the impurities out of it as it works its way slowly through the ground, so that water which was contaminated when it entered the earth may come out pure in a well or spring. All well and spring waters are not however, necessarily safe to drink. In most community water supplies, reliance is not placed solely on natural processes of purification, although they are made use of as aids. Before the water is distributed, it is actually disinfected by chlorine (Chapter IV).

Production of Food for Plants.—We have been speaking, up to this point, of the work of bacteria in decomposing complicated substances, either dead plants and animals or the wastes of animals and man, into simple substances which can be used as food by plants. It was mentioned in the first chapter that the nitrogen of the air is not in a form available for living beings, but that certain bacteria are able to combine it with oxygen and other substances so that it becomes available for plant food. These bacteria live in the soil. The little nodules on the roots of such plants as clover, beans, peas, and alfalfa, contain multitudes of these bacteria which have the power of taking nitrogen out of the air and combining it into substances which are essential for the growth of plants. The great store of nitrogen in the air would be useless for the needs of

living things if it were not for these bacteria. (See Figs. 8 and 9.)

Below a depth of four feet bacteria become less numerous; and at a depth of ten or twelve feet there are usually none. The activities of the soil bacteria cease in very cold weather.

Nitrogen in the air

↓

Bacteria in the soil

↓

Food for plants

↓

Food for animals and man

Fig. 8.—Certain bacteria in the soil make the supply of nitrogen in the air available for the nourishment of plants, and therefore of animals and man. Compare with Figs. 6 and 9.

The Infectious Diseases of Plants.—Not all bacteria in the outside world are friendly to plants, for plants have their infectious diseases caused by organisms, particularly bacteria and molds, just as much as do human beings (Figs. 10 and 108). The blight of fruit trees, the yellow wilt of potato, tomato, squash, and melon plants are examples of plant diseases. The bacteria are carried by insects and are also washed around by rains. Only the burning of infected plants, or the affected limbs of trees, will stop the spread of the infection.

Bacteria in Water.—There are bacteria which live normally in water. They are often present in drinking-

water and are harmless, as they cannot grow in the human body. We take in considerable numbers of them every day. Water, however, which has been polluted with sewage may contain thousands or even

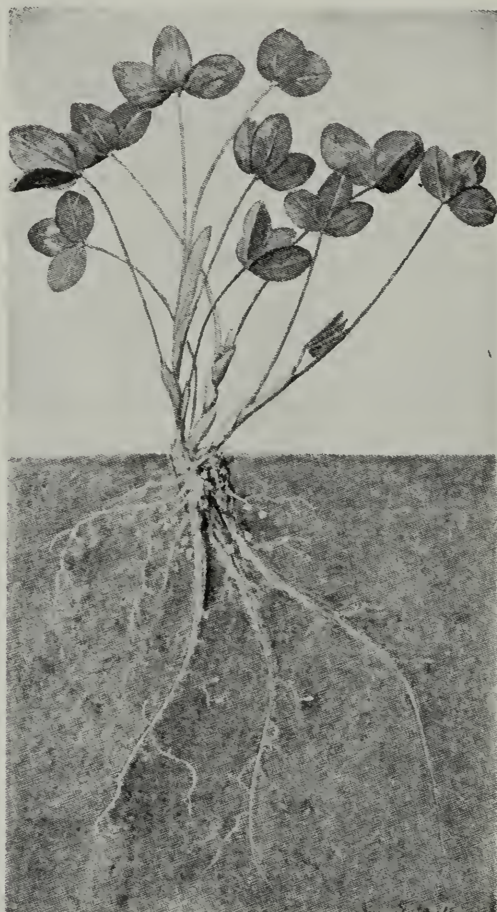

Fig. 9.—A clover plant showing the nodules on the roots which contain bacteria. These organisms can take nitrogen out of the air and build it up into substances which are necessary for the food of plants. (From Arthur I. Kendall, Civilization and the Microbe.)

millions of organisms to the cubic centimeter, and among them the typhoid bacillus. The water of streams, rivers, and lakes is so liable to be contaminated with sewage that it is unsafe to drink it without purifi-

cation. Shallow wells are also dangerous, as they frequently receive drainage from cesspools, barnyards, and sink drains. Water from deep wells is usually but not always, safe. There are no simple tests which tell whether or not water is fit to drink; the only safe way is to boil all suspected water.

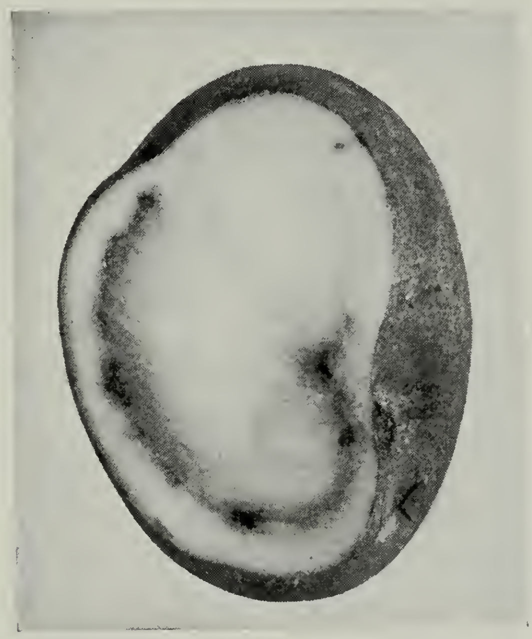

Fig. 10.—Cross-section of a potato showing "brown rot," a disease caused by *Bacterium solanacearum.* (Courtesy of the Laboratory of Plant Pathology, United States Department of Agriculture.)

Bacteria in Air.—The number of bacteria in the air usually depends on the amount of dust. Most of the bacteria are riding around on dust particles. They are usually of the harmless kinds and soon die in the dry air and sunlight. The air of badly ventilated rooms, especially if they are not kept clean, contains many bacteria, and more when occupied, as the inhabitants stir up the dust.

The Growth of Bacteria in Food.—Bacteria grow well in many foods. We eat large numbers of such organisms every day with no bad results. Bacteria flourish so well on some foods, such as beef broth, gelatin, potato, and milk, that these substances are used for cultivating bacteria in the laboratory. *The growth of bacteria in some kinds of food is an advantage.* The good flavors of cream, butter, and cheese are given by the action of certain bacteria growing in them. Varieties of cheese are largely determined by the kind of micro-organisms (bacteria or molds) present in them. For this reason it is customary to add "starters" (certain materials containing the desired bacteria) to cream before it is churned into butter, and to milk which is to be made into cheese.

The changes which micro-organisms bring about in carbohydrates are called *fermentation.* The chief substances formed are acids of different kinds, alcohol, and gases. Many different kinds of bacteria, as well as yeasts and molds (Chapter XXIX), can cause fermentation. There are different kinds of fermentation. One of the most familiar is the production of alcohol from the sugar of fruit juices, as in the making of wine and hard cider. Another familiar kind of fermentation is the change of cider or wine into vinegar, as bacteria form acid from the alcohol. The bacteria which do this collect on the surface as scum, called "mother of vinegar."

The raising of bread is due to still another kind of fermentation. The yeast plant multiplies in the dough and decomposes a portion of the flour starch, forming gas. The bubbles of gas, imprisoned in the dough, raise the bread.

A few bacteria are sometimes present in *eggs* even before they are laid. Bacteria can also pass through the shell after the egg is laid. To make eggs keep longer they are often coated with a substance called "water-glass," which fills up the pores in the shell and thus prevents the entrance of bacteria.

The *spoiling or decay* of foods is caused by the growth of bacteria in them. Tainted meat, rancid butter, rotten eggs, decaying fruit and vegetables are all the result of the work of bacteria.

Distribution and Activities of Bacteria in and on Human Beings.—There are certain bacteria, as we have said before, which can grow only when in contact with the bodies of man or of animals. The healthy human body harbors millions of germs on the skin, in the mouth, and in the intestine; in short, on every surface that comes in contact with the outside world or with food. Most of these bacteria are harmless and never cause disease under any conditions; but others may, under certain circumstances, gain entrance to the deeper parts of the body and cause those changes which we call an infection. Even these harmful bacteria may often live on the surface of the body without producing any disturbance of health. For instance, the germs causing diphtheria, tonsillitis, and pneumonia are frequently found in healthy throats, and we all carry on the skin the bacteria which are the cause of boils and abscesses. The deeper parts of the body and the internal organs may in health contain a few scattered bacteria, or they may be sterile. Each region of the body has its characteristic bacteria.

The *skin* carries large numbers of bacteria, picked up from the various things with which it comes in con-

tact. It is impossible to make the skin absolutely sterile even with the most thorough scrubbing and the application of antiseptics. The germs in the outer layers of the skin can be removed, but it is impossible to get rid of those in the deeper layers. Therefore, rubber gloves are worn in surgical work, as they can be made absolutely sterile.

The *air* which is breathed in contains, as we have seen, particles of dust, some of which have bacteria attached. The air around persons who have been coughing or sneezing contains a germ-carrying mist of sputum, nasal secretion, and saliva droplets. To demonstrate this for yourself, watch someone sneeze while sitting in the sun shining through the window of a darkened room. It is plain that we inhale considerable numbers of bacteria daily. The inside of the nose is especially adapted for dealing with these germs. It is made up of a complicated, scroll-like arrangement of bones, covered with mucous membrane. As the air passes over these surfaces it is not only warmed and moistened, but the bacteria-laden dust sticks to the moist surfaces and is finally carried to the outside in the nasal secretion. In a healthy nose few bacteria can gain a permanent foothold, but if the passageway is stopped up by adenoids or by other obstructions, germs may find suitable conditions for growth.

The *mouth and throat* constantly contain numerous kinds of germs. Bacteria grow readily in a neglected mouth, as conditions of warmth and moisture are favorable, and bits of food around the teeth provide nourishment. Bacteria aid greatly in decay of the teeth. The tartar which collects around the gums is composed partly of bacteria; and the "fur" on the

tongue is a mixture of bacteria, bits of food, and cast-off cells from the tongue. The mouth would contain more germs than it does if it were not for the saliva which acts as a continuous mouth wash. The bacteria are swallowed with the saliva, and many are killed by the acid gastric juice. Persons who have been in contact with pneumonia or diphtheria patients may carry the germs causing these diseases in their mouths and throats, although they may not develop any symptoms.

The *stomach* normally contains few bacteria on account, as has been said, of the disinfectant action of the gastric juice.

The *intestine* of the baby is sterile at birth, but bacteria enter with the first feeding.

The intestine of the adult contains enormous numbers of bacteria, and billions are thrown off every day in the feces. It has been estimated that a grown person excretes daily about 128,000,000,000 bacteria. About one-third of the solid matter of the bowel movement is composed of bacteria. In connection with these immense numbers of organisms it should be remembered that the intestine is about 26 feet long, and conditions of food, warmth, and moisture in it are ideal for bacteria. They are more abundant in the large than in the small intestine.

The *vagina* contains normally certain distinctive nonpathogenic bacteria. The *uterus* is normally sterile. After childbirth, however, it is an excellent place for the growth of germs, which may be carried in, during parturition or afterward, on unsterile hands, instruments, or dressings, and cause puerperal fever.

CHAPTER III

CLASSIFICATION OF BACTERIA. HOW BACTERIA ARE STUDIED IN THE LABORATORY

Morphological classification—Nomenclature—Staining—Hanging drop—The microscope—Cultural differentiation of bacteria—Growth and cultivation of bacteria—Bacteriological media—Hydrogen-ion concentration—Special media—Pure cultures—Methods of identification of organisms—Dissociation.

The classification of bacteria is a very difficult and complicated problem. There are so many kinds, and their relationship to one another is so obscure that even a bacteriologist is often at a loss to know into what group to put a new kind. A bacteriologist with a new kind of germ is in somewhat the same position as a postal clerk with a letter. The postal clerk can easily read upon the envelope what country the letter is directed to, and puts it into the group of letters going to that country. Then the letter is classified as to the state or province, and is removed to the proper group. Then the city is determined, the street, the house, and finally the individual to whom the letter is directed. The directions are all clearly written out.

Now a bacteriologist has to find out for himself in just what classification and group his organism is to be included. He proceeds first of all to examine the shape of the germ. This at once puts it in one of the three great groups into which bacteria are divided, for convenience, according to their shape. He next determines how the germ acts when treated with certain

aniline (coal tar) dyes. These dyes are similar to those used for coloring fabrics and many other materials. This still further classifies his organism. His further procedures depend on the result of the first examinations and will be discussed after we have described the shapes and staining reactions of bacteria.

Morphological Classification.—In the older classifications three great groups of bacteria were recognized on the basis of their form or morphology: the spheres or *cocci;* the bacteria which were elongated but not definitely curved, which were called *bacilli;* and the bacteria which were elongated and also definitely curved into a spiral or a portion of a spiral. These were called *spirillae* and *spirochetes.*

Types of Cocci.—Many species of cocci, after dividing in two during the process of multiplication, remain together in pairs. In order to differentiate these pair-forming cocci they are called *diplococci*, the *diplo* being derived from a word meaning *two* or *a pair.* Other species of cocci cling together in long chains as they continue to divide, and this type is called *streptococci* (strepto = Greek for *chain*). Still other cocci form neither regular pairs nor chains, but irregular groups and masses like clusters of grapes. These are called *staphylococci* (staphylo = *cluster*). One type of coccus forms square groups of four cells and this organism is called *Micrococcus tetragenus* ("producer of fours"). Another type of coccus, of little or no importance medically, produces cubical packets of organisms and is called *sarcinae.*

Nomenclature.—In many instances medical men use the name of a disease to designate a certain organism. For example, the diplococci which cause gonorrhea are

often spoken of as gonococci; and the bacilli which cause typhoid fever are called typhoid bacilli. These terms are still widely used and are a very convenient means of differentiating the various organisms, but the system is not scientific or accurate. Modern bacteriological research has developed a more accurate but somewhat more complicated system of names, and many new terms have recently come into use which it is desirable the student should recognize, although for convenience it may still be preferable in some instances to use the older system. At present the nomenclature of bacteria is in a very unsettled state. Eventually a general system may be worked out and adopted by international agreement of bacteriologists. No claim for consistency of usage can be made in this book. After all, it is the medical names of bacteria which the nurse will hear most often.

The names of many cocci have undergone modification. The diplococcus causing gonorrhea is now called

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Explanation of Plate I

Gram-negative Bacteria

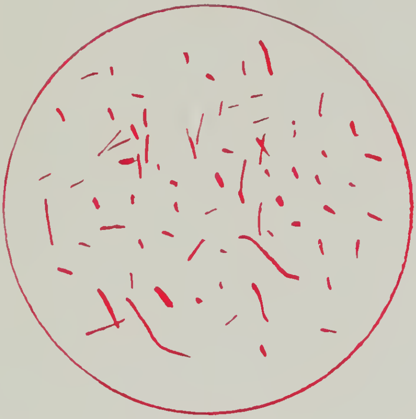
Fig. 1.—Smear of a broth culture of B. typhosus stained by Gram's method. Notice that size and shape vary considerably. All of these various forms are not always seen in a single culture. Magnified 600 times.

Fig. 2.—Smear of a broth culture of B. dysenteriae. Note the similarity to B. typhosus. B. coli and B. paratyphosus have almost exactly the same appearance as B. typhosus and B. dysenteriae.

Fig. 3.—Smear from a broth culture of B. influenzae. These are among the smallest of the ordinary bacteria. Note two or three larger forms. These are not infrequently seen in such smears. Gram's stain used. Magnified 600 times.

Fig. 4.—Smear from a broth culture of gonococci, stained with Gram's stain. Magnified 600 times. These are typical diplococci. Note how they are flattened together. Meningococci present an almost identical appearance.

PLATE I



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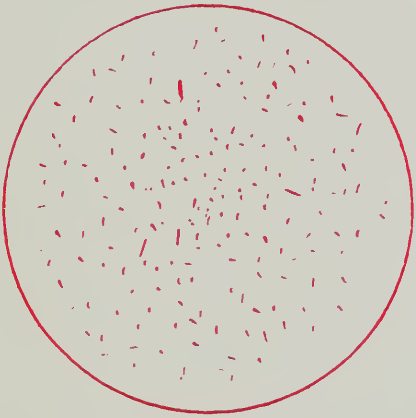

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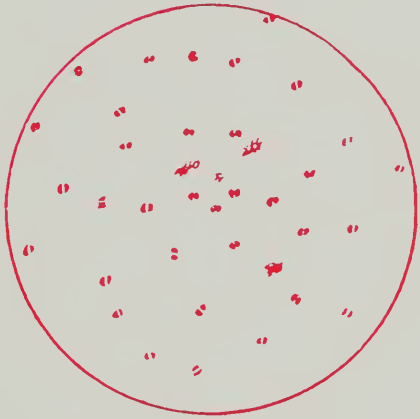

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For explanation see facing page

Neisseria gonorrheae in bacteriological literature, while that causing pneumonia, sometimes called pneumococcus, is called *Diplococcus pneumoniae.* Numerous other changes in names have occurred, which will be discussed later.

The names of most of the bacteria classified as bacilli have also undergone modification, the first part of the names of many of them, as in the case of the cocci, being derived from the name of their discoverer or from some special peculiarity. For example, the bacillus causing typhoid fever, formerly called Bacillus typhosus, is now designated as *Eberthella typhosus,* Eberth being the first to isolate the organism. The bacilli causing one of the two types of paratyphoid fever are called *Salmonella schottmülleri* after two distinguished bacteriologists, Salmon and Schottmüller, who studied the germs. The bacillus at one time thought by some bacteriologists to cause influenza, is now called *Hemophilus influenzae,* instead of Bacillus influenzae. The name *Hemophilus* means *blood-loving* and indicates that the organism has a special affinity for hemoglobin. The organism causing diphtheria, formerly called Bacillus diphtheriae, or the Klebs-Loeffler bacillus (Klebs and Loeffler were two famous bacteriologists who studied the cause of diphtheria) is now called *Corynebacterium diphtheriae* to designate certain relationships to other similar forms. The spore-forming bacilli which grow only in the absence of air, as in a sealed tin can or jar of food, or in a deep wound like a nail puncture or bullet wound, are now grouped together under the title *Clostridium.* Thus, the organism causing tetanus is now called *Clostridium tetani,* and that causing gas gangrene is called *Clostridium welchii.*

These organisms were formerly called respectively Bacillus tetani and Bacillus welchii or the "gas bacillus."

In this book, the correct bacteriological name of each organism as well as its older name will be given at the beginning of the section dealing with that organism.

Staining.—In their natural state bacteria appear under the microscope as tiny colorless balls or rods which are difficult to see clearly. In order to be able to see them distinctly and to study them closely, they are stained with aniline dyes. To accomplish this, a droplet of the fluid which contains them (pus, broth, or blood,) is spread in a thin film on a little piece of glass (called a "slide"). The film is allowed to dry. It is then warmed rather vigorously, by passing through the Bunsen flame four or five times. *Do not scorch the film.* This kills the bacteria and fixes the film to the slide so that it will not wash off. The film is now ready to stain.

There are a number of methods of staining bacteria. Probably the most widely used of the simple methods is by means of a blue dye called *methylene blue.* A few drops of a solution of the dye are put on the film, prepared as above, allowed to remain there about fifteen seconds, and then washed off with a gentle stream of water. The slide is blotted dry (not rubbed) and is ready to examine.

Such a stain shows very well the shape and size of the germ, but there are other stains which give us more information about the organism. The most generally used stain for classifying bacteria was devised by a scientist named Gram and bears his name. It is

called a *differential stain* because it differentiates the bacteria into two groups the *Gram-negative* and the *Gram-positive.*

The Gram stain is done as follows:—

1. After preparing the film as described above, cover it with a solution of gentian violet. (Formula may be found in any text-book of medical bacteriology.)

2. This is allowed to remain for thirty seconds and is then washed off with a gentle stream of water.

3. A second solution called Gram's iodine is now applied for a like interval and washed off.

4. The smear is now bathed for ten to twenty seconds in pure (95 per cent) alcohol. At this point it is necessary to explain the difference between what are called *Gram-positive* and *Gram-negative bacteria.* Gram-positive bacteria will retain the gentian violet and iodine in spite of the alcohol, and when viewed under the microscope will appear dark purple. The Gram-negative bacteria will not hold the stain when the alcohol is applied, and when then viewed under the microscope will have no color at all and will be as nearly invisible as when first put on the slide. Therefore, in order to make these bacteria visible:

5. The smear is flooded with a red dye called safranin, or some other dye having a color which contrasts well with the bacteria already stained purple. One may use Bismarck brown, brilliant green, or eosin. This contrasting stain is washed off after 10 seconds.

6. The slide is now put between two blotters to dry (never rub it), and is ready to examine.

The purple bacteria are the Gram-positive ones, (see Plate II), the pink, brown, or green, as the case may be are the Gram-negative ones. (See Plate I.) Some-

times, in material like feces, both kinds can be seen in the same smear and clearly differentiated.

Some varieties of bacilli are Gram-positive, others are Gram-negative. There are many different kinds of Gram-positive cocci and a considerable number of Gram-negative. Other methods of staining will be discussed later.

Hanging Drop.—There are methods of examining *living* bacteria without staining them. The commonest method is by means of the *hanging drop* (Fig. 17), which will probably be demonstrated in the laboratory. Briefly, it consists in focusing the highest, non-oil-immersion lens of the microscope on a droplet of fluid

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EXPLANATION OF PLATE II

Gram-positive Bacteria

Fig. 1.—Smear from a broth culture of streptococci, stained by Gram's method. Magnified 600 times. These are typical of the spherical bacteria which form themselves in chains.

Fig. 2.—Smear from a broth culture of staphylococci stained by Gram's method. Magnified 600 times. These are typical of the cocci which arrange themselves in irregular clusters. Note a number of pairs like diplococci, and one chain of four cells. These are not infrequently seen in smears of staphylococci.

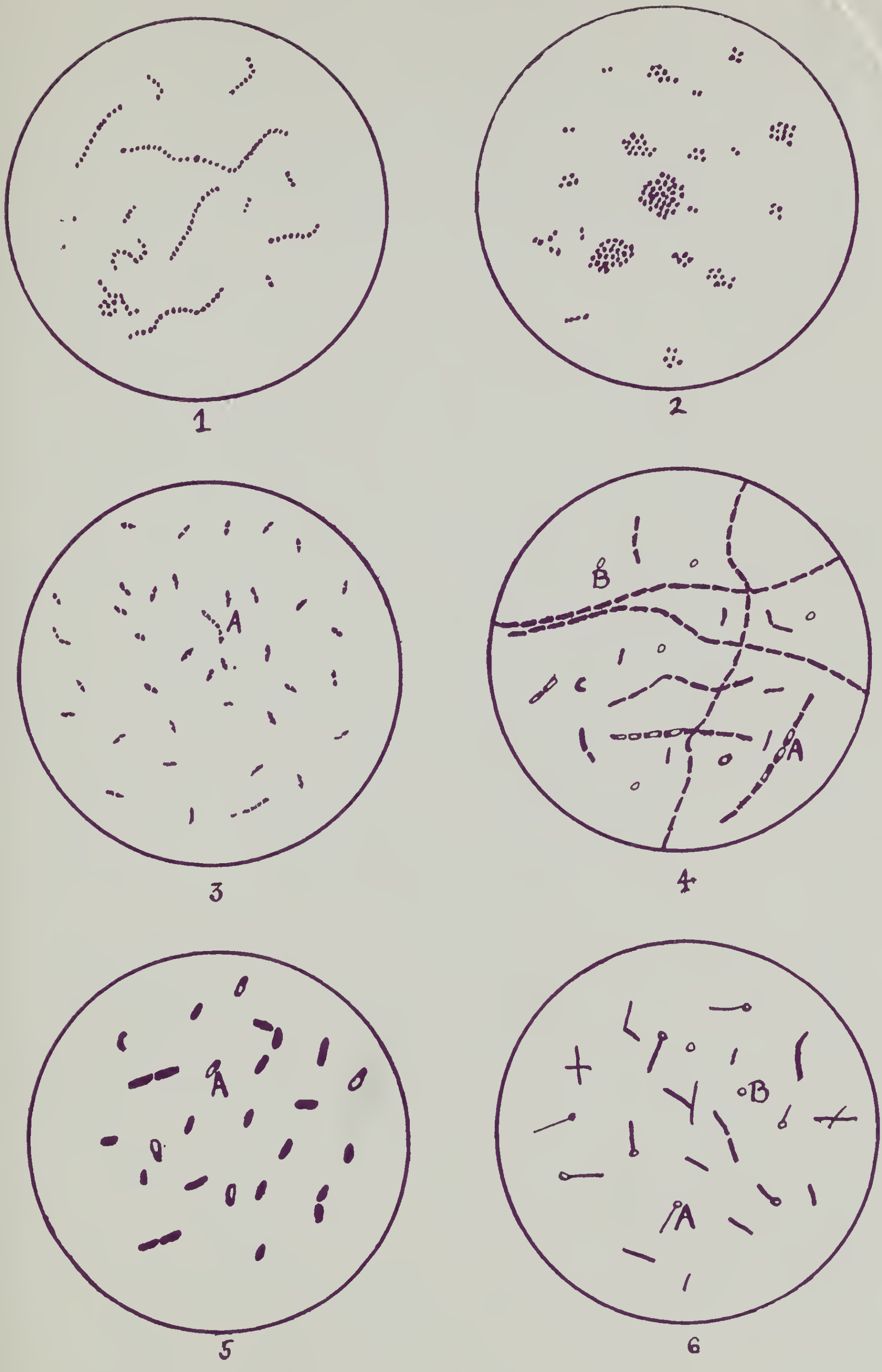
Fig. 3.—Smear from a broth culture of pneumococci stained by Gram's method. Magnified 600 times. Note that the cells occur in pairs, *i. e.*, they are diplococci. Note also that the cells are not perfectly round but elongated or oval, and that they are flattened together. Compare with the gonococci which are also diplococci.

Fig. 4.—Broth culture of B. anthracis. Gram's stain. Magnified 600 times. Note the rather square-cut ends, the chain-formation and the spores. At A are seen bacilli containing spores, at B is seen a spore free from its bacillus. The spores appear as light spaces because the ordinary stains do not penetrate them.

Fig. 5.—Broth culture of B. welchii. Gram's stain. Magnified 600 times. At A is seen a bacillus containing a spore.

Fig. 6.—Broth culture of B. tetani. Gram's stain. Magnified 600 times. Note the spores situated at the end of the bacilli. At B is seen a spore free from its bacillus.

PLATE II



For explanation see facing page

containing bacteria, and observing them there. The *diaphragm* must be partly closed. Much can be learned about bacteria by the use of the hanging drop. For example, some bacteria have the power of motion and in such a drop of fluid under the microscope may be seen darting, rolling, and squirming about, bumping into one another, clinging together for an instant and

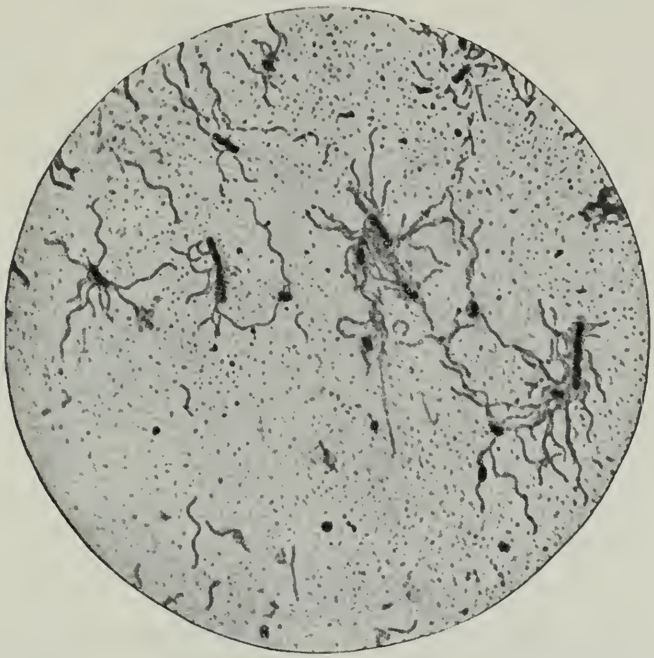


Fig. 11.—The typhoid bacillus, showing the thread-like outgrowths (flagella) by which the bacilli move through fluids. The bacilli must be specially stained to make these outgrowths visible. (Williams.)

then separating again. The power of movement is due to extremely delicate, hair-like outgrowths called *flagella* (Latin for "little whips"), on the sides and ends of the organism. (Fig. 11.) The flagella act somewhat like oars and propel the bacterium through the liquid. The most active bacteria move at the rate of about $\frac{1}{1000}$ inch in a second; that is, they can travel a distance equal to their own length many hundreds of

times in a second. They can move, however, *only in fluid, not through the air* or on solid substances.

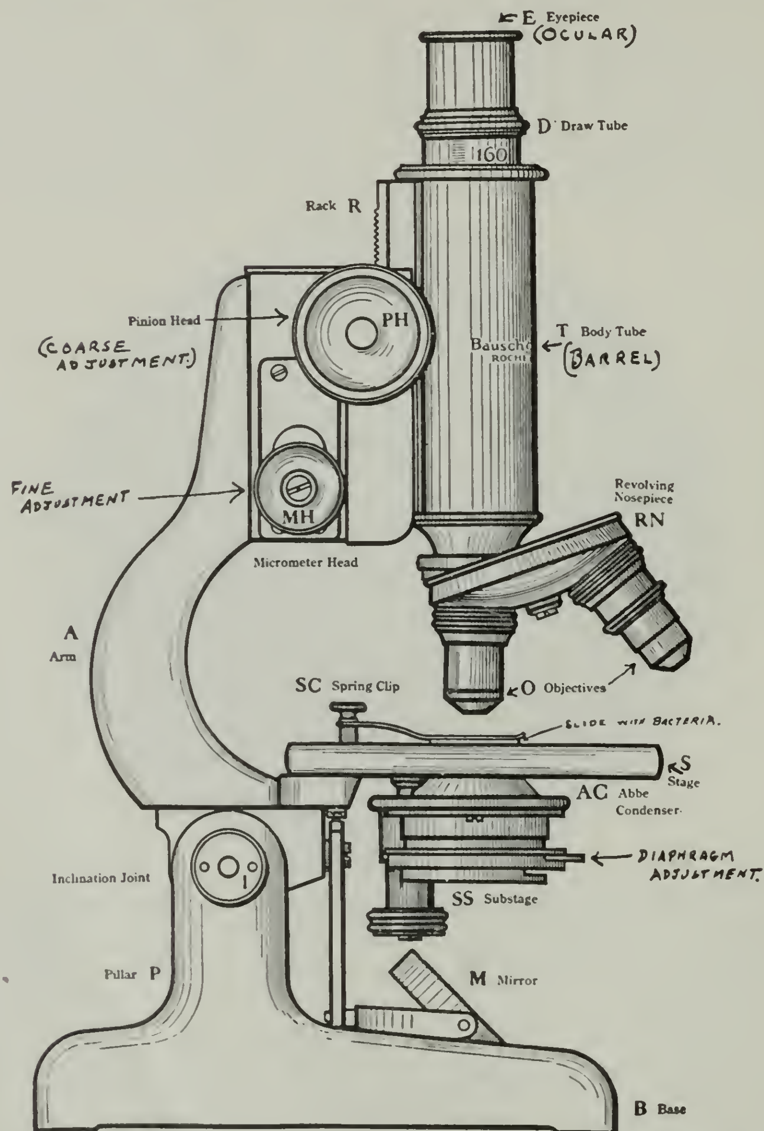


Fig. 12.—Diagram showing various parts of a common form of the compound microscope. Why is it called "compound"? Why is the use of oil necessary in order to see very small objects?

They may, however, be *carried* through the air as "passengers" on dust particles, hands, clothing, etc.

The Microscope.—The modern laboratory microscope is quite expensive and complicated. Figure 12 shows the working parts. A few directions for the use and care of the microscope may not be out of place here.

For the study of bacteria a very powerful lens is necessary. The type most generally in use is called an "*oil immersion*" lens or *objective.* It is difficult for a beginner to focus or adjust an oil immersion lens. First, put a small drop of cedar or Russian oil on the smear to be examined. Place the slide upon the stage of the microscope, smear upwards. Adjust the mirror and diaphragm so that maximum light is reflected up through the smear. Now, with the *large wheel* (coarse adjustment) lower the barrel of the microscope, *watching the lowest point of the objective,* till the latter just touches the oil. Now, *very carefully,* lower the barrel still more until it almost touches the smear itself. Apply the eye to the ocular and raise the barrel with the large wheel *very slowly* until the smear comes into view. Make any subsequent adjustments of focus with the *small wheel,* (fine adjustment).

Never lower the barrel with the large wheel unless you are watching the objective: otherwise you are liable to break the slide and ruin the lens.

Always wipe the oil from the lens, after using, with a piece of soft cotton or lens paper.

Keep the instrument in its box or case to exclude dust.

Do not attempt to clean or repair the inside lenses or mechanism of your instrument yourself. Consult the instructor or someone familiar with such work.

If you have trouble in focusing, it may be due to a poorly adjusted or dirty mirror, or poor source of light, dirty lenses, closed diaphragm, poor stain, or the fact

that the smear is not under the lens, the slide is upside down, or the lens is mashed down on the the slide.

Cultural Differentiation of Bacteria.—At the beginning of this chapter we started to describe the procedures which a bacteriologist would make use of in attempting to identify or classify a new kind of bacterium. First we described the various *morphological* types, and then the differentiation into *gram-positive* and *gram-negative* types, and then the examination of *motility* in a *hanging* drop. These are however only first steps toward the final identification. The bacteriologist must study the *enzymes* of the organism, since, in general, each organism forms enzymes which are peculiar to its species and differentiate it from other organisms.

In order to obtain the bacterial enzymes or to observe their action as they are produced, the bacteriologist induces the organisms to grow in various kinds of specially prepared material where they will multiply most rapidly and in largest numbers.

Growth and Cultivation of Bacteria.—Under the most favorable circumstances a single germ may divide in twenty or thirty minutes, in which case calculation will show that in twelve hours a single organism could give rise to over 68 billion. If conditions were always suitable the earth would be overrun with bacteria; but they, like all other living things, have to struggle for existence, and when conditions are unfavorable they multiply slowly or not at all.

Bacteria must have a suitable temperature for growth, each kind having a temperature at which it flourishes best. The germs which live in the outside world and cause putrefaction grow best at the temperature of mild summer weather (68–75 Fahrenheit);

while those which live in the body and produce disease require more warmth and grow best at about body temperature (95–102 Fahrenheit). The lowest temperature at which bacteria can multiply is about 40 Fahrenheit, and the highest, 110 F. This does not mean that they are killed at these temperatures, since some bacteria are very resistant to both heat and cold; for example, the typhoid bacillus can survive for weeks in ice and there are bacteria which live in hot springs. Extreme heat is more quickly fatal to bacteria than extreme cold. The application of heat is one of the most widely used and efficient ways of killing bacteria. This will be further considered when we study methods of sterilization.

Bacteriological Media.—In the laboratory certain substances are used to induce bacteria to multiply, so that the student will be able to work with masses of them instead of with single cells. The substances used are of many sorts and are spoken of as *media* (singular-medium). One of the simplest is extract broth, which consists merely of weak "beef tea," with a little salt and some dried and powdered, partly digested meat (called *peptone*) added to it. The broth is filtered and then put into test tubes in 5 cc. amounts. The tubes are plugged with cotton to keep out dust, which always carries bacteria with it. They are then heated until sterilized. That is, all the bacteria which have accidentally got in during preparation are killed. The reason for this will be discussed later on. Many bacteria will grow rapidly in such a medium. Usually, however, before putting the broth into the tubes it is necessary, because of a slight acidity, to add a little soda or other alkali. It may be pointed out here that most

of the bacteria which are discussed in this book are very sensitive to too great acidity or alkalinity. It is nearly always necessary to make the degree of acidity or alkalinity just right. This process is called *adjusting the reaction.* By the *reaction* is meant the degree of acidity or alkalinity. The most favorable reaction for most pathogenic bacteria is very slightly alkaline.

Hydrogen-ion Concentration.—Hydrogen atoms, when in solution in water, always carry an electrical charge. These atoms, electrically charged, are called hydrogen *ions.* Acidity of any sort is due to hydrogen ions. If a solution contains a large number of these ions it is very acid, and is said to have a high *hydrogen-ion concentration.* If it is only slightly acid, or is alkaline, it is said to have a low hydrogen-ion concentration. Hydrogen-ion concentration is usually expressed in terms of numbers and the symbol P_H, which stands for hydrogen-ion concentration. A P_H of 14 is the lowest acidity, P_H 7 is neutral, and P_H 1 is the highest acidity in this system. Any P_H between 1 and 7 is acid. Any P_H between 7 and 14 is alkaline.

Special Media.—Various substances are added to broth to help the bacteria to grow, and to see what changes may be produced in them by the bacteria. Blood is frequently added. The broth is then spoken of as "*blood broth.*" Various kinds of carbohydrate such as saccharose, glucose, starch, mannite, or lactose may be added along with the blood or instead of it, and the broth then takes its name from the substance added.

Pure Cultures.—One of the most important steps in studying any bacterium is preparing a pure culture of it. *A pure culture is one in which only one sort of bacterium exists. A mixed culture contains two or more sorts of*

bacteria. A pure culture may be likened to a bed of pansies. In such a bed there is nothing but pansies and we might say that the gardener had made a *pure culture* of pansies. If some geraniums or other sorts of plants were put in the bed also, we might say that the gardener had prepared a *mixed culture.* If weeds got in accidentally we could say that the culture of pansies was *contaminated.* Likewise, when some undesirable bacteria get into our pure culture of bacteria we say that the culture is *contaminated.*

In preparing a pure culture it is very convenient to have a solid surface on which to spread out the mixture of bacteria, and then to pick out the kinds we want and put them in test tubes of media by themselves, there to multiply. A very useful substance for this purpose is agar-agar, which is a form of dried seaweed from Japan. (It is often used also as a cathartic.) When purified and put in boiling water or boiling beef broth, it melts like gelatin and on cooling "sets" to a firm jelly. If some of this beef-broth-agar is sterilized and then poured into a sterile, covered dish and allowed to cool, we can spread out on its surface a droplet of the bacteria-containing fluid (saliva, for instance) and then select the bacteria we wish.

The question at once arises—how, if bacteria are so small as to be invisible, can one pick them from a jelly surface? It is simplicity itself. If the agar contains beef broth it will nourish the bacteria. When the dish is put in a warm place, the bacteria multiply. In 24 hours or perhaps much longer, depending on the species of bacteria being studied, masses of bacteria are usually visible to the naked eye on the surface of the food substance. These masses, each of which is composed of

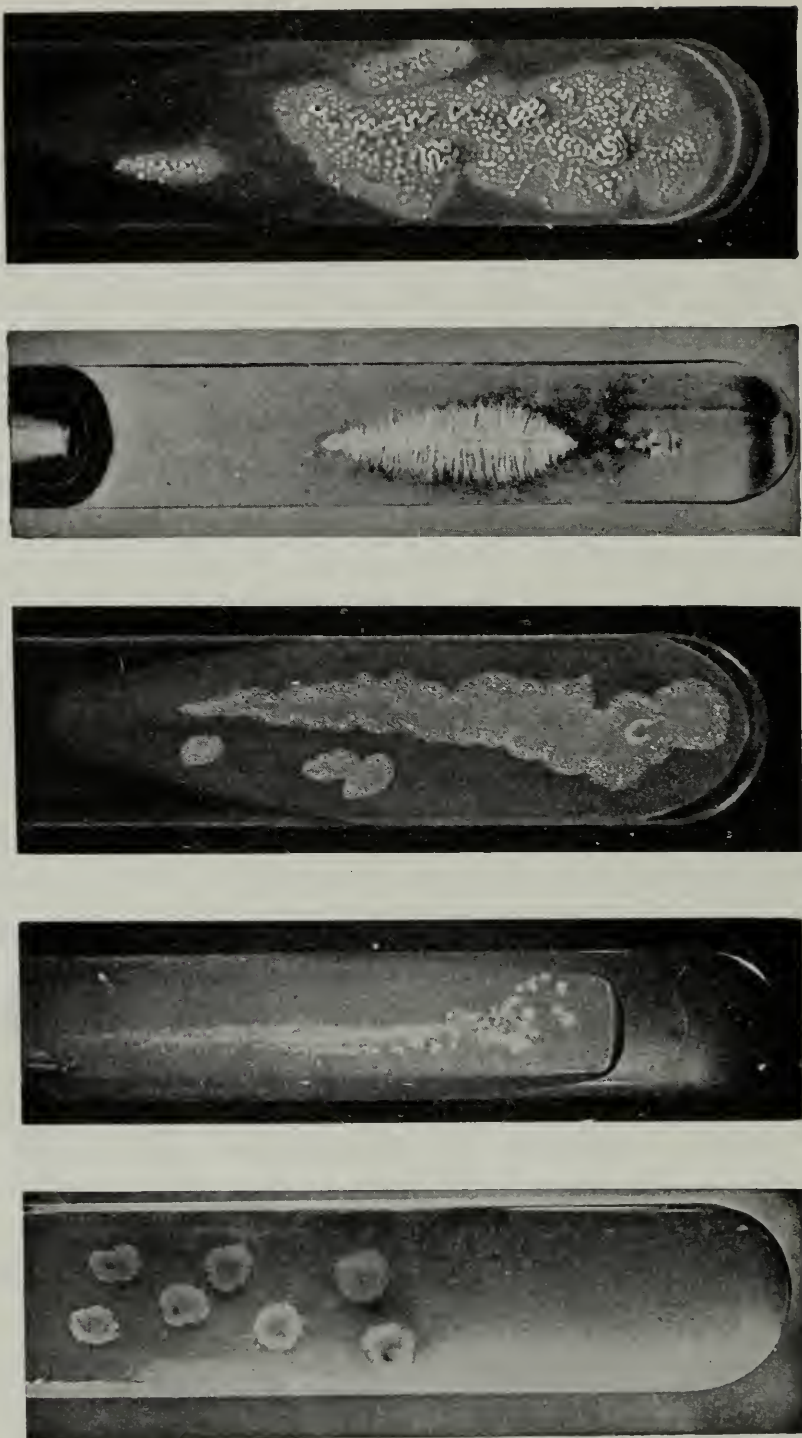


Fig. 13.—Various forms of colonies.

millions of germs, are called *colonies*. Each colony consists of all the descendents of the single bacterium

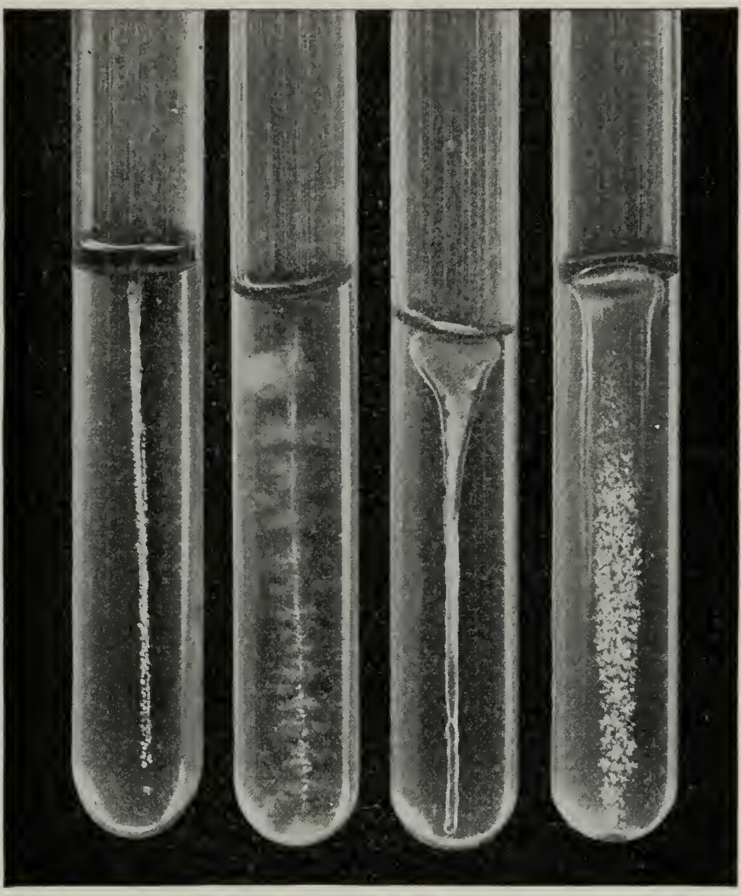


Fig. 14.—Series of stab cultures in gelatin, showing modes of growth of different species of bacteria. The organisms in the first two tubes do not liquefy gelatin; those in the last two produce an enzyme which digests or liquefies the gelatin. Note that the organism in the second tube is an anaërobe, as it grows only beneath the surface of the medium. The organism in the fourth tube of Fig. 10 is also an anaërobe, and forms what is described as a "pine-tree growth." (From Abbott, "The Principles of Bacteriology," Lea and Febiger, Publishers.)

which landed previously on that particular spot. All of the members of a single colony, therefore, being

descendents of a single cell, are of one kind. All that is now necessary, to obtain a *pure culture* from any one colony, is to touch it with the end of a sterile wire and transfer the bacteria which adhere to the sterile wire

1 2 3

Fig. 15.—The fermentation tube. In an uninoculated tube the medium completely fills the closed arm. These tubes show B. coli communis (Chapter XV) growing in (1) dextrose, (2) lactose, and (3) saccharose broth. The organism forms acid and gas from dextrose and lactose, but not from saccharose. The gas from the growth in the upright arm rises, pushes down the broth, and collects at the top (1 and 2). (From Hiss, Zinsser and Russell, "Text Book of Bacteriology," D. Appleton & Co., Publishers.)

to whatever kind of medium we desire. This in turn is *incubated* for as long as necessary.

Colonies of different bacteria vary in appearance. (Fig. 13.) Some look like dewdrops; others are white

and glistening like the head of a white pin; still others have various colors. When bacteria grow in broth they sometimes cause a cloudiness, sometimes a surface film called a pellicle, and sometimes a sediment.

Fig. 16.—Method of inoculating a tube of medium by means of a swab. Before the plugs were removed, the tops of both tubes were passed through the flame to singe the free parts of the plugs and to sterilize the lips of the tubes. The plugs are held between the fingers in such a way that the ends which go in the tubes do not touch anything. The swab carrying the bacteria is removed from the first tube and inserted into the tube of media without coming in contact with anything, is wiped *gently* over the surface of the medium, and is then put back in its tube in the same careful way. The nurse in dispensary and public-health work is often obliged to inoculate tubes, and she should therefore practise the method until she can do it accurately.

Methods of Identification of Organisms.—As has been said, the bacteriologist identifies the organism in a culture by several methods. *First*, he smears it and stains by Gram's method, and then examines it with the microscope. This shows whether it is a coccus, a bacillus, or a spirillum, and how the individual bacteria are arranged, whether in bunches, chains or otherwise,

and whether it is a member of the Gram-positive or the Gram-negative group. Bacteria, however, are so limited in their shapes and arrangements that microscopic examination alone is insufficient to identify them. Organisms which stain alike and look the same under the microscope may be entirely different in other characteristics.

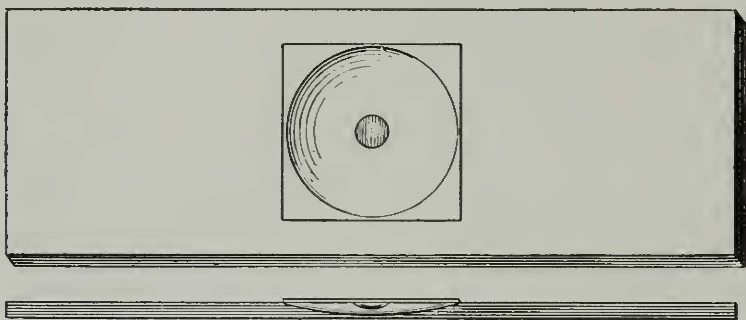


Fig. 17.—The "hanging drop" seen from above and in profile. (From Mallory and Wright, "Pathological Technique.")

Second, he studies the way an organism grows on different food substances, the appearance of its colonies, their size, shape, color, and other characteristics. This, combined with its appearance under the microscope and its staining reaction, often gives definite clues as to what germ we are dealing with.

The third method of study is to find out what *chemical changes* the particular organism which we are studying can bring about in various test substances. As has been mentioned, bacteria can cause, by means of their enzymes, a great variety of chemical changes very quickly under favorable conditions. They can decompose complicated substances into simple ones and build up complex compounds from simple materials. They can form acids and gases, clot milk, liquefy gelatin, and bring about the changes which we call

putrefaction, fermentation, and disease. Not all bacteria can do all these things, but the ability of each kind of organism to bring about certain chemical changes is known. We therefore study what our organism can do, as well as what it and its colonies look like. Practically, this is done, as has just been indicated, by transferring droplets of a pure culture into tubes of sterile milk, gelatin, broth, solutions of various carbohydrates and other substances, and examining the cultures at the end of 24 hours and later. It is important to realize that not only in the laboratory can bacteria produce these chemical changes, but that they are continually bringing about similar reactions in the world around us. We shall study some of these activities further when we take up the study of the different kinds of bacteria.

Fourth, in studying disease-producing bacteria, it is frequently necessary to inject or inoculate them into *animals* (Figs. 18 and 19). This is the only way in which the action of bacteria on the living body can be studied directly, exactly, and under varying conditions, since we cannot experiment on human beings. Animals react to many kinds of bacteria in much the same way as man reacts, and the organisms cause the same kinds of changes in their bodies. It should be pointed out, however, that some bacteria which are fatal to man will not infect animals, and vice versa, and that different animals may react differently to a given bacterium. Bacteriology and medicine could never have developed without the study of the action of bacteria on animals and the experiments which can be performed on them. The animals most often used for this purpose are guinea pigs, white mice, and rabbits.

Furthermore, the inoculation of animals may be useful in making a diagnosis on patients, because some bacteria grow better and more quickly in the bodies of animals than in test tubes. For instance, tubercle

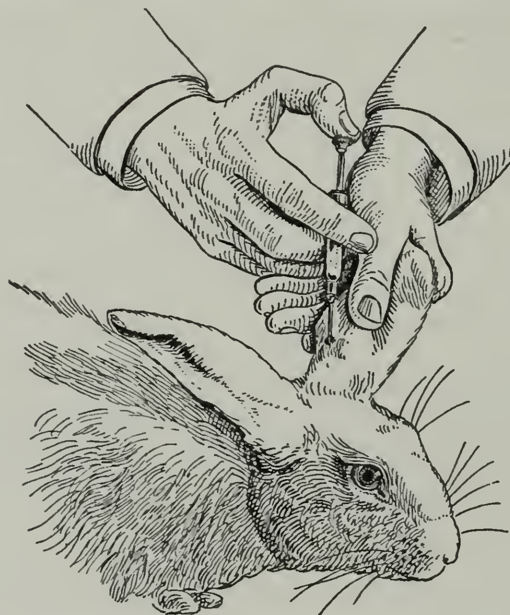


Fig. 18.—Injection of bacteria into a rabbit through a vein in the ear. (McFarland.)

bacilli are difficult to cultivate in the laboratory, but by inoculating a guinea pig with the suspected material (sputum, urine, or pus) a positive diagnosis may be obtained more quickly and surely. The animal will rapidly develop tuberculosis, and an autopsy will demonstrate the condition. It is of the greatest advantage to a patient to determine as soon as possible what bacteria are causing his trouble, and the inoculation of animals often helps toward this end.

Fifth, the effect of the *serum* of certain specially treated animals upon certain kinds of bacteria is sometimes very striking and offers an excellent method of identification. Various *serological tests* (see Chapter

VII) based upon this fact are made use of in all diagnostic laboratories. The names of some of these tests with serum are the *agglutination*, the *precipitin*, the *bacteriolytic*, and the *complement fixation tests*.

Fig. 19.—Inoculation of a guinea-pig in the lower abdominal region. A fold of skin is pinched up and the needle entered into the fold. The skin is then released, and the injection slowly given. A swelling indicates that the injection is subcutaneous. (From Kolmer "Infection, Immunity and Biologic Therapy.")

The names of many of these tests are masked by the names of the individuals who discovered them.

Dissociation.—There has recently appeared in the literature of bacteriology a great deal concerning a phenomenon called dissociation. The subject and the

numerous theories connected with it are extremely interesting but very complicated and not entirely settled. A few well-established facts stand out, however, and these may be touched upon here.

In examining agar plates previously inoculated with a pure culture of a single kind of organism, it has been observed frequently that at least two types of colony (Fig. 20) can be found after incubation. One type is

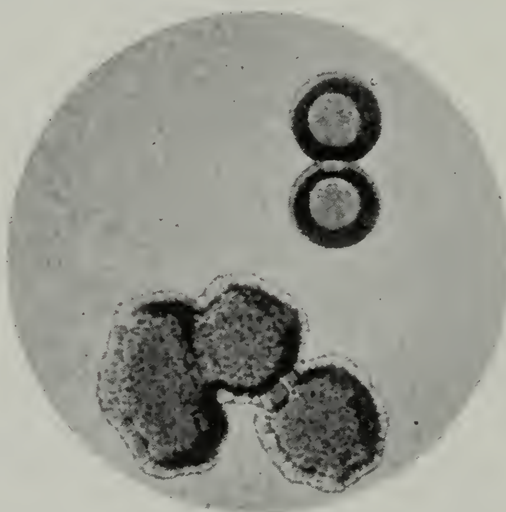


Fig. 20.—Smooth (S) and rough (R) colonies of B. typhosus. (After Arkwright, Medical Research Council, A System of Bacteriology in Relation to Medicine, Vol. I, by permission of the Controller of His Britannic Majesty's Stationery Office, London, England.)

smooth, glistening, moist, and has even edges. This is called the *smooth* or "S" *type* of colony. The other common type is rather dry and rough, and sometimes wrinkled, and its edges may be irregular. This is called the *rough* or "R" *type.* Each type apparently originated from the pure culture, and the culture is said to have *dissociated* when these different types appear. Dissociation of a culture into R and S types sometimes occurs spontaneously and unexpectedly, sometimes it can be brought about by special methods.

By careful procedure, one type may be changed into the other. Some bacteriologists describe other types, besides the S and R, but these are less stable and less commonly observed. Some workers also describe *dissociants*, (as the changed types are called), which no longer resemble true bacteria but rather the filterable viruses, in being invisible and in passing through porcelain filters (see Chapter XXV). These filterable types however have yet to be established beyond question, and their significance is obscure.

Bacteria in S-type colonies frequently differ from those in the R-type colonies in being more virulent and possessing a capsule. Cultural differences as well as differences in chemical composition (antigenic or immunological differences) are also described. This whole subject is being hotly disputed among bacteriologists at the present time.

CHAPTER IV

STERILIZATION, DISINFECTION AND ASEPSIS

How bacteria are killed—*Sterilization:* (*A*) By Heat. (1) By moist heat: pasteurization; boiling; live steam; steam under pressure. (2) By dry heat: baking; incineration—(*B*) By Filtration—(*C*) *Disinfection*—Disinfectants—Phenol coefficient—Fundamentals of chemical disinfection—Methods of food preservation—*Asepsis:* development of antiseptic and aseptic technic; responsibilities of the nurse.

We have seen in the preceding chapter, how desirable and necessary it is to be able whenever required, to cultivate bacteria in large numbers. It is equally desirable and necessary in special situations to be able to kill or eliminate bacteria. A nurse who has a good working knowledge of the various methods of killing or eliminating bacteria, as well as correct ideas as to when and how to make use of each method for doing this, will have advanced a long way toward success in nursing technic, both in the ward and in the operating room.

In the first place, it is necessary to become conscious of the invisible. One must bear in mind constantly that bacteria are always present everywhere if special precautions have not been taken to kill or eliminate them. It is also necessary to realize that although most bacteria in the outside world are harmless, and we take millions of them into the body every day, pathogenic bacteria are often mixed with them. It is in great part for the destruction and elimination of

the latter that certain modern features of surgical, public-health, and nursing technics have been devised.

These special features are based on well recognized and simple facts to which it will be well for the student to give particular attention. We shall deal, first, with simple methods of killing bacteria and then discuss the more elaborate procedures, and finally the more modern methods of *asepsis*.

How Bacteria Are Killed.—As has been previously pointed out, the active, vital part of all living cells is protoplasm. When protoplasm is subjected to certain procedures, it is altered chemically as when oxidized, or coagulated as when heated or treated with certain chemicals. In both cases it ceases to live. *Heat* and certain *chemicals* are therefore very widely used to kill bacteria. Certain forms of *radiant energy* such as ultraviolet light and radium emanations, also kill bacteria, but their use is limited to special situations and conditions. They are too expensive for general use.

Sterilization.—By sterilization is meant *the removal of all forms of life.* The agents by which it can be accomplished are *heat, chemicals, radiant energy*—all of which have been mentioned—and in addition, *filtration through clay cylinders.* The choice of a sterilizing agent and its successful application require knowledge, discrimination, and caution.

(A) Sterilization by heat is extremely useful in a wide variety of situations. There are a number of methods of applying heat, each of which has its particular uses and advantages. *Moist* heat is always more effective than dry heat because *the more moisture the protoplasm contains, the more easily it coagulates.* Some articles however are injured by moisture, others by

dry heat, so that one must be careful which form of heat is used. The method must depend on the results desired and the material to be treated.

1. **Sterilization by Moist Heat.**—(*a*) **Pasteurization.** About 1860 Pasteur discovered that the deterioration of wines, which occurred when they were stored for some time, was due to the continued growth in them of the yeasts and other organisms which had produced the wine flavors. He found that he could arrest the growth of these organisms, and thus prevent spoiling of the wine, by heating it to about 60 C. (140 F.). Pasteur's process was hailed as a great discovery and was named after him. Today, the same process is applied extensively to milk, and less frequently to some other foods. When milk is heated for half an hour at 60 C., all the disease germs which may be present in it by accident, are killed, and the milk is not injured. Among the bacteria thus destroyed are those which cause typhoid fever, dysentery, tuberculosis, undulant fever, scarlet fever, septic sore throat, and diphtheria. Hundreds of other bacteria in the milk survive pasteurization, but none of them are known to be harmful when taken into the stomach. It is thus apparent that a large number of pathogenic bacteria are easily killed by temperatures below boiling.

(*b*) **Boiling.**—Very few harmful bacteria can withstand 100 C. (the temperature of boiling water) for more than three or four minutes *if they are in a moist condition.* The process of boiling quickly coagulates all active protoplasm, and is therefore most generally used for sterilizing surgical instruments, glassware, the dishes of infectious patients, drinking water, food, and all articles which are not injured by being made wet and

hot at the same time. The presence of water helps the process of coagulation and makes boiling very effective.

(*c*) **By Live Steam.**—Some articles which cannot or should not be sterilized by boiling can be heated to the same temperature by exposing them to live steam in a covered container for any desired length of time. "Live" or "streaming" steam is steam as it rises from

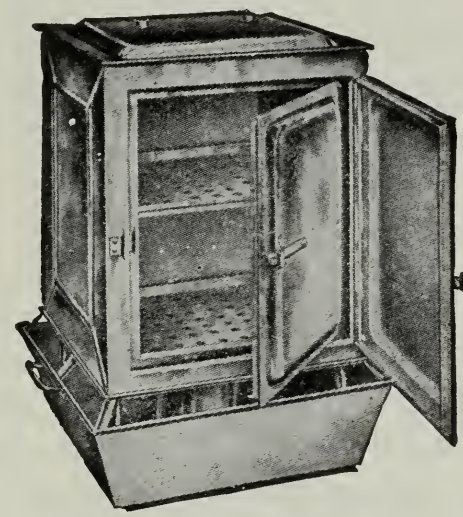


Fig. 21.—An Arnold sterilizer. The water is boiled in the pan underneath, and the steam passes through the perforated bottom of the sterilizing chamber, then through openings in the top, and down the sides between the inner and outer jackets. How could you fix up a home-made sterilizer embodying the same principle?

the surface of boiling water, *i. e., not under pressure.* Sometimes the exposure is repeated in order to kill spore-forming bacteria. The process is then called *fractional, intermittent,* or *discontinuous* sterilization, because it is done in successive parts. A special apparatus for fractional sterilization (Fig. 21) is called, after the German bacteriologist who devised it, the Arnold sterilizer.

The reason for repeated exposures to live steam is that some kinds of bacteria have developed means of resistance to heat and other conditions unsuitable for life, by the formation of what are called *spores*. This process is not common among disease-producing germs, but frequent among those living in the outside world. When an organism is about to form a spore, a glistening speck appears near one end. (Plate II, Figs. 4, 5, and 6.) This increases in size, becomes surrounded by a dense protective covering, and is then called a spore. This may leave the bacillus, which after the formation of the spore, is nothing more than an empty shell, and may be blown about with dust. The spore is dormant like the seed of a plant. In spore form the germ has a remarkable power of resistance to heat, cold, drying, disinfectants and other unfavorable conditions. When conditions again become favorable (moisture and warmth are necessary) for the life of the germ, the spore "sprouts," or germinates, changes back to the ordinary form of the organism, and goes on growing. Spores can remain alive for a long time, even for years.

The bacterium, before the spore has formed, is said to be in the *vegetative state:* Now if we apply streaming steam for an hour on Monday, we kill all the vegetative forms, but the spores may not be killed. If the material containing the spores be sufficiently moist, and be kept at body temperature overnight, the spores germinate and become vegetative. On Tuesday streaming steam is again applied for an hour and the newly vegetated bacteria are killed. In order to be doubly safe, the heat is generally applied a third time to kill any spores that may have been slow to germinate the second

day. This method is not used to any extent in hospital work, but it is employed in the laboratory and is

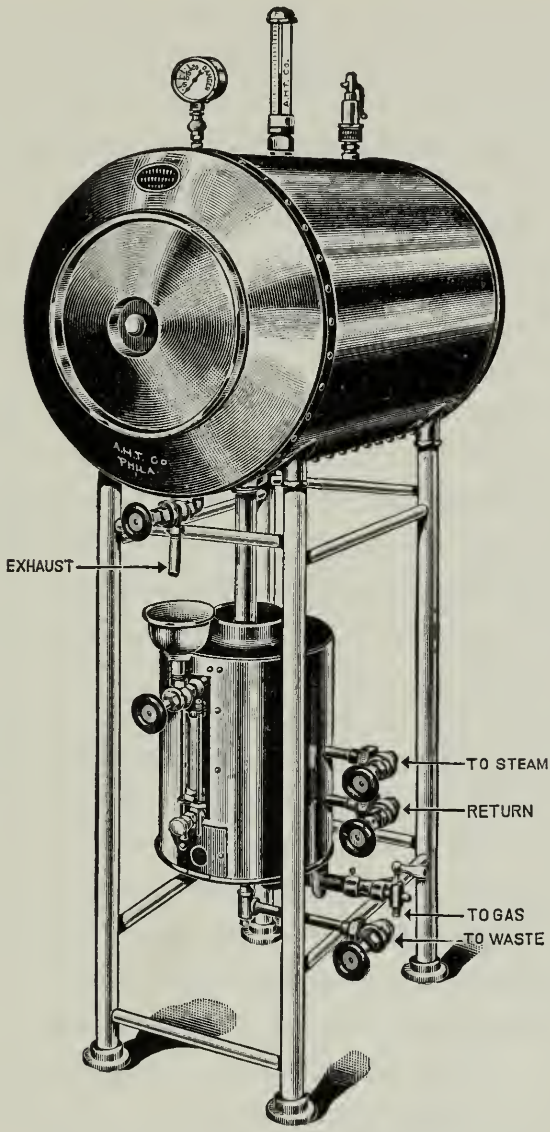


Fig. 22.—Horizontal type of autoclave.

widely used by housewives in the so-called "cold-pack" method of canning.

(*d*) **By Steam under Pressure.**—Many articles, such as packages of surgical dressings, are not invariably

sterilized by exposure to live steam, because they may contain very resistant spores which will not vegetate in contact with dry gauze. Furthermore, the length of time required for the completion of fractional sterilization is inconveniently long, and also many delicate solutions are changed chemically by long and repeated heatings. In addition, steam condenses on the articles and leaves them soaking wet.

In order to sterilize with steam certainly and quickly, steam under pressure in the *autoclave* (Fig. 22) is used. An autoclave is essentially a metal cylinder with a door which can be screwed down tightly. The closed cyclinder is filled with steam from a boiler until the pressure reaches the desired point. During her training in the operating room, every nurse becomes familiar with the management of the autoclave.

The advantages of steam under pressure depend on the following facts:

The student knows from her study of physics that when steam is held in a closed container and its tendency to escape and expand is prevented, it is compressed, or is, as we say, "under pressure." Its temperature then rises far above that of boiling water or of steam which is not under pressure, and it develops a tremendous power of penetration. These characteristics of steam under pressure give it special value for sterilization. The temperature of the steam depends on the amount of pressure, which is expressed in pounds to the square inch.

By allowing all the air in the chamber of the autoclave to escape and be replaced by the incoming steam, the spaces in the center of masses of material may be brought quickly into contact with the steam.

The actual amount of water present as steam in the pressure chamber is usually small; consequently the articles sterilized are not wet with much condensed steam when they are removed from the autoclave.

The very high temperature and the moisture combine to perform their work of coagulation quickly, so that 15 to 20 minutes under 15 pounds pressure is usually sufficient to kill all bacterial life, including spores.

It must be understood that steam pressure alone and not air pressure is responsible for the coagulation. The air is an obstruction to the process of coagulation. For this reason any one using the autoclave must be sure that:

1. All the air is allowed to escape and is replaced by steam;
2. The pressure of the steam reaches at least 15 pounds to the square inch;
3. The pressure is maintained for at least twenty minutes.

If these conditions are met and if the masses or bundles are not too large, the autoclaved material will be sterile.

Autoclaving may be used for any objects which are not injured by moisture or by the high temperature. Dressings, clothing, food, bacteriological media of most varieties, as well as saline and other solutions may be sterilized satisfactorily in this way.

2. **Sterilization by Dry Heat.**—(*a*) **Baking.**—We have seen that in the application of moist heat comparatively low temperatures may be effective in killing bacteria because protoplasm coagulates readily when in contact with abundant water. Many articles, however, especially glassware for the laboratory and operating room,

are not satisfactory if sterilized by any of the moist methods, and must therefore be subjected to dry heat. This is most conveniently done in an oven. The temperature must necessarily be much higher than in the autoclave, because moisture is absent and coagulation does not occur readily. In addition, longer exposure is needed to kill spores. Ordinarily, two and a half hours exposure to a temperature of 175 C. is sufficient. This application of heat usually just begins to turn cotton and paper a light brown color.

Baking in an oven is often desirable in home nursing. The exposure may be controlled by leaving the materials in the oven just long enough to turn the wrappings or a piece of newspaper, a light brown. A slow oven is preferable, as it allows the heat time to penetrate.

(*b*) **Incineration.**—Burning in a fire or furnace (incinerator) is a cheap, effective, and widely used method of disposing of undesirable material such as garbage, sputum cups, infected dressings, and any contaminated material which it is not desirable to save. In the laboratory, incineration is made use of on a small scale. The bacteriologist heats his platinum loop to redness in the Bunsen flame; the pathologist sears the surface of an organ at autopsy with a red-hot knife blade before passing a sterile instrument through the surface to obtain bacteria for study from the interior of the organ.

(B) **Filtration.**—It is possible to sterilize various fluids by passing them (if they are not too viscous) through a filter made of fine, unglazed clay. The apparatus used for this purpose is shown in diagram in Fig. 23. The entire apparatus is sterilized in the autoclave. A rubber tube connected with a suction pump

is then attached to the stem of the flask and the fluid to be filtered is poured upon the clay filter-cylinder "candle." The suction draws the fluid through into the flask, but the bacteria and all other particles are held back by the clay. The fluid is then removed from the flask with sterile pipettes. *There are some organisms much smaller than bacteria which may pass through*

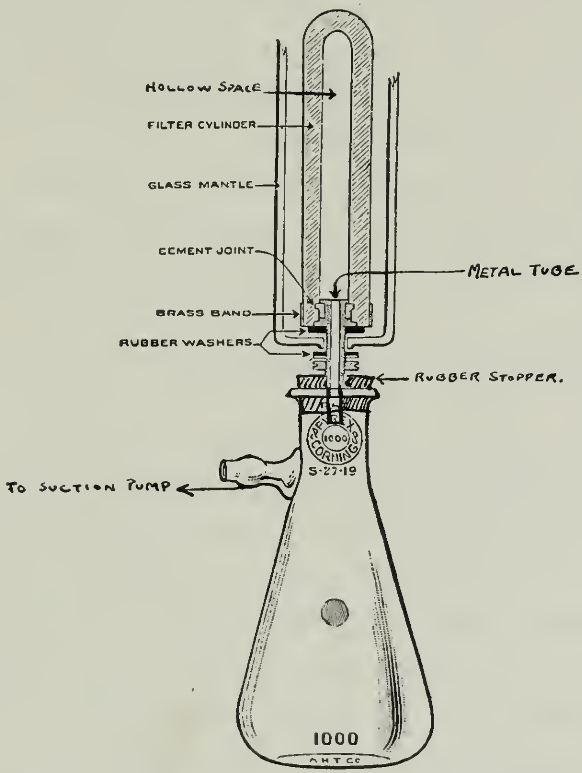


Fig. 23.—Arrangement of bacteriological filter.

such filters. These are called filtrable or ultramicroscopic viruses and will be discussed in a subsequent chapter.

(C) **Disinfection.**—Up to the present point, we have discussed chiefly the methods by which material may be made completely free from all life—that is, sterilization. By disinfection is meant the *removal of dangerous*

or infective bacteria only, often leaving numbers of harmless organisms alive, as in pasteurization. Disinfection is a limited term and means simply the removal of infective bacteria, and not necessarily of all organisms. As, however, it often kills all bacteria, it is included here as one of the methods of sterilization. Disinfection is most conveniently carried out by means of chemicals, and those used for the purpose are called disinfectants. They can be applied to the skin, the mucous membranes, surgical instruments, thermometers, and many other things.

The term "*antiseptic*" is often incorrectly used in place of disinfectant. An antiseptic, however, may really not kill bacteria at all, but merely *prevent their growth,* thus preventing sepsis. Although the terms are sometimes used interchangeably, they have different meanings.

Disinfectants.—Many chemical substances have the power of killing bacteria, but comparatively few are suitable for general use. The nurse will become familiar with the disinfectants most in use in hospitals. Disinfectants differ in their power to destroy organisms; some are much more effective and reliable than others. Many of the widely advertised patent germicides have comparatively little disinfectant action. Bacteria also differ in their power to withstand disinfectants; some are killed easily, others are quite resistant. Spores are extremely hard to kill with chemicals.

No one disinfectant is suitable for all substances or under all conditions. Some are too irritating or too poisonous to use on the skin and mucous membranes or in wounds; others rot cloth or rust metal; others are

too expensive for general use. We can merely mention here in a preliminary way a few of the most common and most widely used disinfectants. In her further studies and experience the nurse will learn much more about their properties and special uses.

Bichloride of mercury is one of the most valuable disinfectants. In a dilution of 1 to 1000 it kills most non-sporeforming bacteria within half an hour. Its disadvantages are that it corrodes metals, is irritating to the skin, and is very poisonous. It also coagulates substances containing albumen, like sputum, blood, and pus. Bacteria, when encased in coagulated material escape its action. It is therefore not good for disinfecting material which will coagulate when it is added.

Mercurochrome, also a substance containing mercury, has been developed within recent years. It is less poisonous than bichloride and is used locally in 1–4 per cent solution, and sometimes intravenously in special cases in 1 per cent solution, 5 mgms. per kgm. of the patient's body weight.

Mercurochrome is an example of the *antiseptic dyes*. Many organic dyestuffs are powerful antiseptics, and some of them have a selective action on one group of bacteria or one organism, as compared with another.

Carbolic acid (phenol) is a very useful disinfectant. It is generally used in 3 per cent solution. It does not cause coagulation, is less irritating to the skin, and does not corrode metal or rot cloth.

Lysol and *creolin* contain carbolic acid and certain tar derivatives. They are used in 1 to 2 per cent solution, and are good germicides. Lysol contains soap and may be used in very dilute solutions as a hand wash or for

wiping floors or furniture. It penetrates where solutions free from soap will not penetrate.

Formalin in 10 per cent solution has a wide range of usefulness as a disinfectant. It may be used to disinfect feces, urine, sputum, and similar substances, and also clothing. It deodorizes as well as disinfects. The material to be disinfected should be allowed to stand in the solution at least two hours. It is very irritating, but otherwise has the same advantages as carbolic acid.

Tincture of iodine and 50 *per cent alcohol* are used in disinfecting the skin.

Lime is valuable in situations where it is necessary to use large quantities of a germicide, which under those conditions must necessarily be inexpensive. Its disadvantages are that it rots fabrics and attacks plumbing fixtures. It is used either as "milk of lime," which is made by adding one part of lime to eight parts of water, or as chlorinated lime, the so-called "chloride of lime." Milk of lime should be freshly prepared each time that it is to be used, and added in quantity equal to the amount of material to be disinfected. The mixture should stand at least two hours. *Chlorinated lime* is used in 4 to 5 per cent solution.

Chlorine and chlorine preparations are invaluable disinfectants for certain purposes. Several chlorine preparations owe their power to the liberation of chlorine. *Dakin's solution,* a highly efficient disinfectant used most often to irrigate infected wounds, is prepared by adding chlorinated lime to a solution of sodium carbonate, and after filtration of this solution, boric acid is added. *Chlorine gas* in solution in water (called "liquid chlorine") is applied in the disinfection

of *water supplies*, and its use represents the most important advance in the art of water purification. Two or three pounds of chlorine per million gallons of water is the usual dose. Chlorination is also used for the disinfection of sewage.[1]

Phenol Coefficient.—The concentration of a disinfectant is important. If a solution is too strong, its use is wasteful, and it may also ruin materials or cause undue irritation of the skin or mucous membranes. If it is too dilute, it will not accomplish its purpose. In order to know in what strength solutions of disinfectants should be used, they are tested by comparing their action with that of a known solution of pure carbolic acid (phenol). If the disinfectant being tested is just as efficient as the phenol, it is said to have a *phenol coefficient* of 1. If it is twice as effective as phenol it is said to have a phenol coefficient of 2, and so on. Ordinarily, if a disinfectant has a phenol coefficient of 2, it is necessary to use only half as much of it as one would of phenol. This is not always so, however, because much depends on the kind of bacteria to be killed. The different species differ considerably in their resistance to various chemicals. The location of the bacteria may also be a factor causing variation.

Fundamentals of Chemical Disinfection.—Several *general principles* in connection with disinfectants are important to remember. First, a *hot* germicidal solution is much more powerful than one of the same strength cold. Second, sufficient *time* must be allowed for the disinfectant to act. Very few disinfectants act immediately, even in strong solutions. Third, dis-

[1] For a continuation of this discussion, see Chapters IX and X in Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

infectant solutions have very little power of *penetration* into the interior of solid masses. Therefore the material, such as feces or sputum, must be broken up and thoroughly mixed with the disinfectant. It is extremely important to do this; otherwise the bacteria in the center of the mass will not be exposed to the disinfectant and killed. Fourth, the disinfectant must be sufficiently *concentrated* to act within the time allowed.

Methods of Food Preservation.—Food is preserved from the destructive action of microörganisms by one of four methods; by heat (canning); by cold (cold storage); by the use of preservative substances of various kinds, such as sugar, salt, and vinegar; and by drying. It is now possible to preserve every kind of food material by the use of appropriate methods. Food preservation is of the greatest importance in our complicated modern life. It provides people both in cities and in the most isolated regions with an abundance and variety of food in wholesome condition. It prevents waste by making possible the saving of food when and where it is plentiful, so that it may be available in time of scarcity. *All methods of food preservation depend on bacteriological principles.* Some methods, like drying and pickling, have been practised for centuries, while canning and cold storage are modern developments.

The *principles of canning* are just the same as those of surgical sterilization; that is, the destruction by heat of all bacteria present, and the protection of the material from the entrance of other germs. In the household this is done either by boiling or by intermittent sterilization. By the older method, the fruit and

vegetables are boiled, the jars, covers, and rings are sterilized by steaming in water, the jars are filled to overflowing, and sealed air-tight while boiling hot. By the newer "cold pack" method, the fruit and vegetables are put into the jars cold and are sterilized by steaming in a boiler on three successive days. This method preserves the color and flavor better than does the method of boiling. In canneries steam under pressure in an autoclave is used.

The principle underlying *cold storage* is that food can be preserved for a long time if it is kept at so low a temperature that bacteria cannot develop. The bacteria present in the food when it is put in cold storage are not killed, but they cannot multiply. Meats, fish, and poultry are frozen; eggs, fruits, and vegetables are kept just above the freezing-point. Some foods deteriorate slowly in cold storage. There is, however, an unreasonable prejudice against cold-storage goods. They may, as a matter of fact, be really "fresher" than goods which have been kept a shorter period of time at higher temperatures.

Pickling in either brine or vinegar preserves food because a strong salt or acid solution kills many microörganisms. Large amounts of sugar also prevent the growth of bacteria; this is the reason for putting up fruit cold in a thick syrup. It is also the method of preparation of condensed milk. Dried meats, vegetables, and fruit do not spoil because they contain too little moisture for the growth of bacteria. In the process of smoking meat or fish the material is not only dried, but certain antiseptic substances pass into it from the smoke.

Pasteurization has already been discussed. As applied to milk, it consists in heating milk to 140 F. for

thirty minutes, followed by rapid chilling. This kills not only practically all *disease germs*, but also most of the acid-producing bacteria which normally occur in milk, so that pasteurized milk sours very slowly. Practically all the milk sold in large cities has been pasteurized.

Asepsis.—We have spoken of sterilization (killing all forms of life) and disinfection (killing pathogenic forms). We now come to the more difficult and highly technical process of asepsis, which means the absence of infection or sepsis, and depends on technic *to keep bacteria away from an already sterile field.*

The surgical operation, large or small, and the nursing procedures which involve surgical principles, are the most familiar examples of aseptic technic. In an operation, all the instruments, dressings, sheets, gowns, and gloves are sterile to start with. Masks are worn, so that if anyone inadvertently coughs or sneezes, the spray will not *contaminate* the field or *infect* the patient. Hands which have touched anything unsterile are not allowed in the sterile field or to touch anything which is to enter it. The surgeon wears gloves both to prevent the bacteria on his hands from infecting the patient, and also, in infected cases, to avoid being infected himself. There is no attempt to kill bacteria during most operations, but extreme care is taken to keep bacteria out.

Aseptic technic is also used in obstetrical deliveries and in the care of infectious diseases. The bacteriologist also makes use of aseptic principles to avoid contaminating his cultures, and in her work in the bacteriological laboratory the nurse has usually her first practical experience with the method.

Development of Antiseptic and Aseptic Technic.—As applied to surgery and obstetrics, aseptic technic developed later than antiseptic technic, of which, in fact, it was a natural outgrowth. The history of its development is of dramatic interest. Modern surgery and obstetrics were impossible until aseptic technic had been developed. *Semmelweis* (1818–1865,) assistant in the obstetrical department of the General Hospital in Vienna, was the pioneer of antisepsis in obstetrics, and the first to recognize that puerperal fever is a septicemia. Simply by insisting that doctors, medical students, and midwives should wash their hands in calcium chloride before conducting labor, he reduced the mortality on his wards from 9.92 to 1.27 per cent (1847).

Before the days of antisepsis, surgery was largely of an emergency nature and was limited to the more exposed parts of the body. It was undertaken only when death would have been inevitable without it, and even small operations on clean cases were regularly followed by suppuration, which in itself was often fatal. The intelligent use of antiseptics in surgery began about 1860. The proof that suppuration of wounds was caused by bacteria was brought in 1880, and this was a turning point in surgical technic. At first it was thought that organisms got into the wound from the air; hence Lister and the surgeons of his time operated under a spray of carbolic solution, which drenched the operating field and its surroundings (Fig. 24). The instruments and dressings were soaked in carbolic solution. While the antiseptic method in surgery represented an immense advance on no precautions at all (Fig. 25), it had great disadvantages. It

injured the tissues, did not always prevent infection, and frequently led to carbolic poisoning.

The introduction of rubber gloves in 1890 by Dr. William Halsted of the Johns Hopkins Hospital had far-

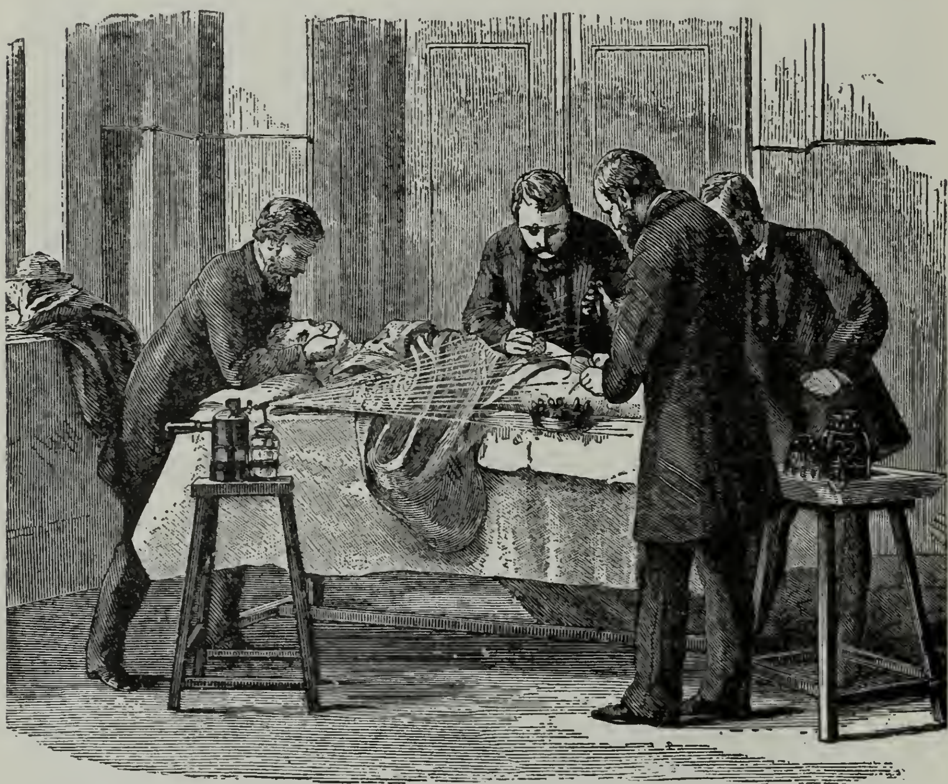


Fig. 24.—Lister operating with carbolic spray. Representing the general arrangement of surgeon, assistants, towels, spray, etc., in an operation performed with (supposed) complete aseptic (antiseptic) precautions (1882). Note the carbolic spray playing over the field of operation. (W. Watson Cheyne.)

reaching consequences. From that time the use of moist and dry heat gradually supplanted the general use of antiseptics, and aseptic technic in approximately the form in which we know it today, grew up during the eighteen-nineties.

Responsibilities of the Nurse.—Aseptic technic can be learned only by long and conscientious practice, but a useful preliminary is to watch a bacteriologist or a surgical group, and explain why they do the things they do.

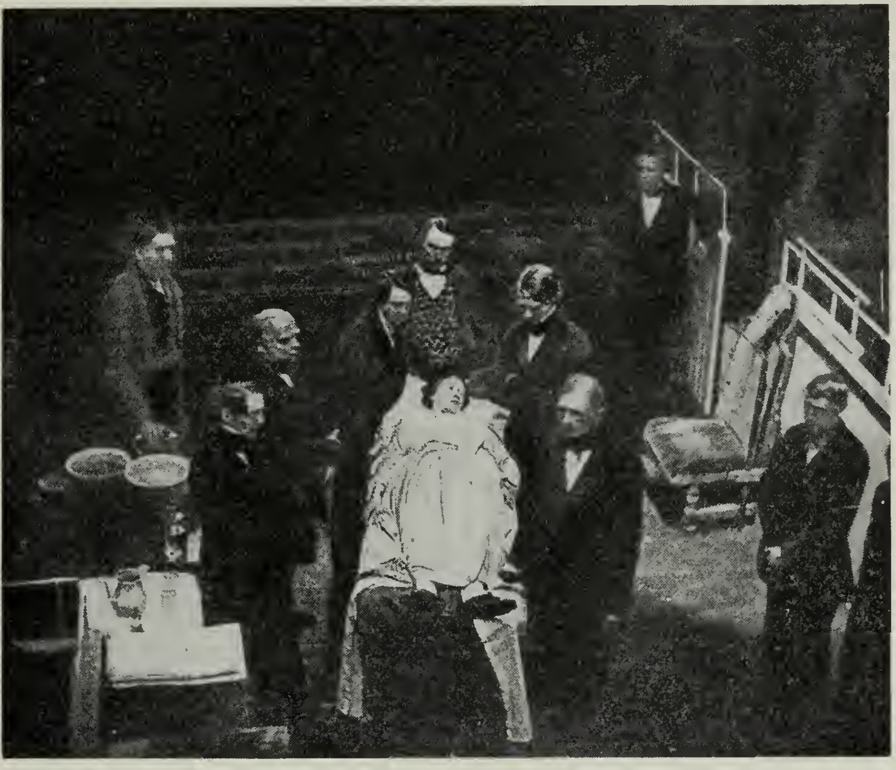


Fig. 25.—How an operation was performed in pre-antiseptic days. The patient has a tumor of the jaw. This picture is of great historical interest, as it shows the first public demonstration of ether anesthesia in the Massachusetts General Hospital, October 16, 1846. (Reproduced from "The Influence of Anaesthesia on the Surgery of the Nineteenth Century," by J. Collins Warren, M.D.)

Watch for sources of contamination. When in the presence of any aseptic procedure, it is indispensable to think constantly of possible sources of contamination, and scrupulously to avoid them. A good aseptic technic is one of the surest signs of a well-trained nurse.

In so-called clean surgical cases, in which there is no infection before operation, germs may be carried into the wound on the hands of the surgeon. They may, if the assisting nurse has been careless or not well trained in aseptic technic, be carried into the wound on instruments or dressings which have not been perfectly sterilized, or which have been contaminated after sterilization. Germs from the patient's own skin, even though it may apparently have been thoroughly disinfected before operation may also cause infection of surgical wounds. The whole object of *aseptic technic* in surgery is to *keep the wound free from microörganisms*, and this demands teamwork on the part of the surgeon, the assistants, and nurses. It begins with *preparation of the patient* in the ward and the *sterilization of dressings and instruments*.

The hands of the surgeon, the assistants, and the nurses are most frequently responsible for wound infection. The most essential part of the sterilization of the hands is thorough *scrubbing in hot running water with soap and sterile brush.* This is much more effective in disinfecting the hands when combined with the use of disinfectants. Scrubbing and disinfecting the hands is not a mere ceremony, but an important matter of business, to which undivided attention should be given. It is absolutely necessary for the nurse to learn to carry out aseptic technic strictly. This requires, in the first place, undivided attention to the matter in hand, for it is in moments of carelessness that breaks occur and the sterile object touches someting unsterile. It requires in the second place the development of "*the aseptic conscience*," which will make her feel the responsibility of correcting her breaks in technic and the mistakes which no one but herself has observed.

When it comes to nursing dangerous infectious diseases, the nurse's own health and even her life and those of others may depend entirely on her technic. A nurse who has a great fear of nursing infectious diseases must, at heart, have little confidence in her own knowledge of how disease is transmitted and of her ability to protect herself by her aseptic technic.

Since however, even in spite of the best technic accidental infections do sometimes occur, it is reasonable for a nurse to request that she be artificially immunized to the disease which she is to handle, provided a method is known of producing artificial immunity to that particular infection. Good hospitals will insist upon such protection.

CHAPTER V

INFECTION

Infection—Portals of entry—Virulence—Toxins—Resistance—Defenses of the body: mechanical barriers; inflammation; phagocytosis; antibody formation.

Infection.—An infectious disease may be regarded as a struggle between an attacking force and a defending body, the bacteria representing the invaders. Both sides have their means of offense and defense. We shall first consider the struggle from the side of the bacteria.

Bacteria may gain entrance to the tissues of the body and grow in them, injuring them and producing symptoms. When this happens the result is called an *infection.* The word has a very broad meaning and is used for conditions which vary greatly in severity. Some infections are so mild that they cause almost no discomfort; others are fatal. A pimple, for example, is a trivial infection of the skin; typhoid fever is a serious and often fatal infection of the blood, intestine, and other organs.

Portals of Entry.—There are *certain routes or pathways by which bacteria enter* the body and cause infections. The most important of these pathways are through the skin, the respiratory tract (nose, throat, tonsils and lungs), the mouth and gastro-intestinal tract, and the genito-urinary tract. Any small cut or abrasion, or sometimes perhaps even very thin and delicate

membranes such as the conjunctivae may serve as a portal of entry for bacteria.

The pathway by which an organism enters the body is usually of great importance in determining whether or not disease will occur. Each kind of disease germ has its favorite pathway, and the majority of them can cause an infection only if they enter over their own particular route. Thus, typhoid bacilli rubbed into a wound of the skin would probably give rise to no trouble, while the same organisms, if swallowed, might cause fatal typhoid fever. On the other hand, the cocci which cause boils may give rise to no harmful effects when swallowed, while if rubbed into the skin or a wound they would produce a severe infection.

Bacteria floating in the air enter the body through the *respiratory tract.* The germs of tuberculosis and pneumonia may be scattered through the air attached to particles of dried sputum. They are also thrown out in the spray formed by the patient during coughing or sneezing, and may be breathed in by any one nearby. Organisms entering through the nose or mouth may take one of several paths. They may be swallowed, and so reach the stomach and intestines; they may stay in the nose and throat and produce an inflammation there, as, for instance, a cold;[1] they may locate on the tonsils, as in the case of diphtheria and tonsillitis; they may pass on to the lungs, as they do in pneumonia and tuberculosis. From the various portals of entry organisms may pass into the circulating blood and start an infection in

[1] A variety of infections of the nose and throat are loosely included in the term "cold" as commonly used, but actually there is a single, definite condition which may properly be called a cold and according to very recent reports this is caused by a filterable virus.

some of the internal organs or in the brain and spinal cord.

Virulence.—After gaining entrance to the body, the pathogenic bacterium must have some means of maintaining itself there, otherwise it would perish. It accomplishes this because of the property spoken of as *virulence.* Virulence may be regarded as a combination of *aggressiveness* and *toxicity.*

By an aggressive organism is meant one which tends to disregard the normal resistance of the body and to enter the blood or tissues, growing there more or less vigorously at the expense of the victim. The skin is inhabited by large numbers of bacteria which are not very aggressive. They remain on the skin without causing an infection because they are readily held in check by the normal protective mechanisms of the body. Other bacteria require only a very slight opportunity in order to gain a foothold and invade the tissues in spite of the protective agencies which oppose them.

Toxicity simply means poisonousness. If the bacterium is poisonous, or if it secretes a poisonous substance, as was mentioned in Chapter I, then it need not be very aggressive in order to be virulent and to do damage to the body. It may lack aggressiveness almost entirely and not even be able to survive in contact with live tissues. Yet, if a few very toxic germs lodge in the throat on the tonsils or in small foci such as abscesses at the roots of the teeth, or the wound made by the puncture of a nail, or a bit of crushed and necrotic tissue, they may, by producing their poison, which is absorbed and carried all through the system, kill their victim.

This is exactly what happens in diphtheria. The bacteria which cause the disease lack aggressiveness

almost entirely. Yet by maintaining a slight foothold, they can fatally poison the patient. They are extremely virulent because of their toxicity but not because of their aggressiveness. Other bacteria, like the anthrax bacillus (Plate II, Fig. 4), are just the reverse. Although possessing little toxicity they are very virulent because of tremendous aggressiveness. Indeed, they may grow so extensively in the blood as to clog up some of the smaller vessels, especially those that supply the brain and heart, and produce death in this way.

Variations in Virulence.—Virulence may vary. A highly pathogenic organism may become *attenuated* or lessened in *virulence* or *pathogenicity* by growth in certain unfavorable situations or in contact with certain substances. Bacteria which are kept constantly in laboratory culture media may lose some or all of their virulence for animals or human beings. On the other hand, by passing organisms of relatively low virulence from one animal to another, their virulence may be enormously increased. It has been suggested that some organisms, ordinarily of low virulence, acquire more and more virulence by rapid passage from one susceptible person to another until finally they become so virulent that they cause a definite illness in practically everyone with whom they come into contact, the result being an epidemic.

The real causes of changes in virulence are very little understood. We know only that in certain situations and as a result of certain procedures, virulence alters. Just what change is produced in the bacterium is not known.

Toxins.—Poisonous bacteria produce their effect in one of three ways. First, they may consist of poisonous

protoplasm. Second, they may form a poisonous, enzyme-like substance (*toxin*) which remains enclosed within the cell membrane. Such a toxin is called an *endotoxin* (endo = *inside*). Third, they may form a toxin which diffuses outward through the cell membrane. Such a toxin is called an *exotoxin* (exo = *outside*).

The toxins of bacteria are very complicated chemically. Indeed, little is known about them from a chemical standpoint, except that they are derived from, and somewhat resemble protoplasm or protein. Just how they injure the tissues of the body is not clearly understood.

The toxin of each bacterium differs from all others. Thus, diphtheria toxin, an exotoxin, injures the kidneys and heart particularly. Tetanus toxin (also an exotoxin) injures certain nerves and thus produces the spasms of lockjaw. Toxins help to weaken the defense of the body, and thus enable the bacteria to injure their victim more effectively.

Resistance.—Now let us view the struggle between bacterium and body from the standpoint of the defending body—the host.

Defenses of the Body.—The body has very efficient means of protecting itself against bacteria.

(*a*) **Mechanical Barriers.**—In the first place, the body is protected by simple mechanical means.

The unbroken skin is a perfect protection against most bacteria; they cannot get through it. If, however, the *skin* is injured or torn, bacteria may enter the underlying tissues. Here they may find favorable conditions for growth and multiply, causing an inflammation, usually with the formation of pus. Breaks and injuries

of the skin which are so small that they are overlooked may offer a place of lodgment for germs. The danger of neglected accidental wounds and cuts is that they may be the starting point of a serious infection.

The conjunctiva is protected by the motion of the eyelids and the constant washing of the tears, which carries the bacteria down into the nose. Certain bacteria, however, may find the conjunctiva a portal of entry.

The lungs are safeguarded by the complicated arrangement of the nasal passages with their moist mucous membrane. These act as a trap which catches most of the incoming bacteria. The mucous membranes are covered with a slimy secretion in which dust, bacteria, and other foreign particles are caught like flies on fly-paper. The secretion is then removed by sneezing or other means. Leukocytes which have engulfed bacteria may usually be found in the normal nasal secretion. The bacteria which get by and pass into the lungs are carried out again by the action of the cilia on the cells lining the trachea and bronchi. This action has been referred to as a "physiological escalator."

The intestines are protected by the acid gastric juice, which kills many harmful bacteria.

(*b*) **Inflammation.**—If the mechanical barriers to the entrance of bacteria become disabled through injury or weakness caused by other disease, malnutrition, or other cause, bacteria may enter the tissues and set up an infection. Such a condition is seen when a cut or a burn becomes infected, or when a person who has long suffered from some wasting illness like cancer, develops pneumonia.

When bacteria invade the body they cause certain symptoms by the action of their poisons on the various

organs. They also damage the tissues at the place where they enter the body or where they locate. The tissues respond to this injury; they try to stop it, to get rid of the bacteria, and to repair the damage. The visible part of this *effort of the tissues* we recognize as *inflammation.* Inflammations of various parts of the body are familiar in everyday experience, as boils, infected scratches or cuts, etc. Every kind of germ causes inflammation when it invades the body, but some give rise only to very slight changes. There are two grades or degrees of inflammation, *acute* and *chronic.* An acute inflammation is one which lasts only a short time, perhaps a number of days; a chronic one, weeks or months.

The obvious changes present in every acute inflammation are redness, swelling, heat, and pain. These may be observed in an abscess or an inflamed joint. The redness is due to the increased amount of blood and dilatation of blood vessels; the pain, to compression and injury of the small nerve branches in the tissue. The swelling and heat are caused partly by the large amount of blood and partly by the complicated changes which are going on in the tissue. Poisonous substances formed by the bacteria injure the cells of the tissue. These substances attract the white cells of the blood, or the *leukocytes,* to the injured spot.

Inflammation is usually although not always accompanied by the formation of *pus.* A mild inflammation may heal without the formation of pus, and in some severe inflammations, such as erysipelas, no visible pus is formed. When the inflammation and pus formation are localized in one spot, we have an *abscess.* In the healing of severe and extensive acute inflammations,

and in chronic inflammation, new tissue is formed to replace that which was destroyed. This is usually *connective tissue.* All *scars* are formed of connective tissue.

Bacteria are the cause of inflammation in the great majority of cases, but it is possible to have inflammation caused by irritating substances when no bacteria are present. Poison ivy or mustard, for instance, can produce an acute inflammation of the skin. Heat and cold can also cause inflammation, as we see in a burn or frost bite. *Inflammation in its broadest sense is the response of the body to injury of any kind.*

We see that inflammation has both an injurious and a beneficial side. The damage caused by the bacteria or other injurious agents is harmful. The response of the tissue and the activities of the leukocytes are protective, because they tend to destroy the bacteria and repair the damage which they have caused. The study of what happens in inflammation gives us further insight into the struggle between the body and the invading bacteria which takes place in the infectious diseases. If the entrance of bacteria into the body were not followed by some protective reaction, like inflammation, everyone would soon succumb to an infection.

(*c*) **Phagocytosis.**—The body is also protected by the leukocytes and certain tissue cells which devour bacteria (Figs. 45 and 50). This process is called phagocytosis (phago, from the Greek word "*to eat,*" and cyte, "*cell*"). The leukocytes which possess this ability are chiefly of the polymorphonuclear variety (Fig. 2).

There are other cells in the body which act like leukocytes in engulfing foreign particles. They differ from

leukocytes, however, in being at the same time parts of certain organs and do not move freely. For example, there are *phagocytic cells* in the liver, spleen and bone-marrow.

Phagocytosis is by no means limited to the leukocytes and the tissue cells just mentioned, but it is shared by many unicellular organisms (Figs. 3 and 101), some of which live as parasites in the body, others having an independent existence in the outside world. It is one of the ways in which these organisms get their food. If the ingested substance can be used for food by the cell, it is digested by the action of a special enzyme. Bacteria within leukocytes disappear in this way.

The action of leukocytes has already been described in Chapter I. They take up other things as well as bacteria—bits of useless or harmful material of various kinds, such as coal dust, or the remains of red corpuscles. They can dispose of a comparatively large mass by removing it piecemeal. The "core" of a boil is gradually carried off by the leukocytes, as are also silk and catgut ligatures, and, in part, the exudate in pneumonia (Fig. 44). The leukocytes are attracted by anything abnormal or unusual in a tissue or in the blood, such as bacteria, a slight injury, a hemorrhage, the presence of a poison, any dead or useless tissue, or a foreign body. This attraction is probably of a chemical nature.

Certain infections always cause an increase of the leukocytes in the circulating blood; *i. e.*, a *leukocytosis*. Others do not increase the leukocytes. Among those in the first group are infections caused by staphylococci, streptococci, and pneumococci; in the second, typhoid fever, measles, influenza, tuberculosis, and syphilis.

There is a simple method of determining the actual number of leukocytes in a cubic millimeter of blood by diluting it and counting the leukocytes under the microscope. The leukocyte count is thus an aid in the diagnosis of infectious diseases. It has also some prognostic value, in that, in those infections accompanied by a leukocytosis, a high leukocyte count indicates a vigorous reaction of the body to the disease.

(*d*) **Antibody Formation.**—In addition to mechanical barriers and the action of leukocytes and other phagocytic cells, the body has *more complicated* systems of defense through the formation of *chemical substances*, the antibodies, *called out under the stimulation of the organisms themselves.* These substances will be discussed in the following chapters.

CHAPTER VI

IMMUNITY

Definition—Historical note—Types of immunity—Natural immunity: species, racial, and individual immunity—Naturally acquired immunity—Subclinical infections.

Definition.—Bacteriology has two fundamental aspects: first, the study of the organisms themselves, their forms, activities, relationships to one another and to other groups of organisms. This division may be called *systematic bacteriology.* We have just made a beginning on the discussion of some points in systematic bacteriology, and shall continue it throughout the book.

The second great division of bacteriology is *immunology, i. e., the study of the defenses of the body against invading organisms.* We have mentioned the mechanical barriers which the body interposes to the inroads of bacteria. Immunology, however, is concerned not with the mechanical but with the *chemical* defenses of the body, and more especially with those which, strange as it may seem, are stimulated by the very organisms themselves.

Historical Note.—Immunology developed somewhat later than systematic bacteriology. Its scientific study dates from the latter part of the nineteenth century, and three great names are associated with the early investigations—Pasteur, Ehrlich (see Frontispiece), and Metchnikoff. In the latter part of his life, Pasteur

developed the principles of immunity in connection with the prevention of rabies (Chapter XXVI) and certain diseases of animals. Metchnikoff (Fig. 26), a Russian working in the Pasteur Institute at Paris, was the first to study the part played by the leukocytes in immunity (1884). Ehrlich in 1897 developed his famous "side-chain" theory to explain the mechanism of immunity. The possibilities of serum therapy in

Fig. 26.—Elie Metchnikoff (1845–1916). (From Garrison "History of Medicine.")

the treatment of disease were opened up in 1890 by the studies of v. Behring on immunity to tetanus and diphtheria.

Since the beginning of this century, the growth of our knowledge of immunity has been continuous and has come from many directions. At the present time it is unfolding rapidly and is constantly giving us new insight. The historical background will acquire more meaning as we proceed with the discussion of the nature of immunity, the immunological relations of the various

bacteria, and the treatment of disease along immunological lines.

Types of Immunity.—The student has learned in the preceding chapters that the body is constantly in contact with bacteria, since millions of these organisms inhabit the skin, the mouth, the intestine, and every surface which comes in contact with the outside world. These bacteria are ordinarily prevented from gaining entrance to the blood and tissues of the body by the skin and the cells which line the mouth, stomach, intestines, respiratory tract, and vagina. Even if a few pathogenic bacteria do gain entrance, as through a cut or pin-prick or other injury, they usually lack the ability to multiply in the tissues if the body is healthy, and they soon die without doing any harm, the dead and sometimes the still living bacteria being removed by the leukocytes.

It is the death of these bacteria in the tissues or blood which chiefly interests us at present. Why do they not invade the body further and cause disease? The reasons are manifold and extremely interesting. The phenomena responsible for the resistance of the body to the invaders are spoken of collectively as *immunity.*

Immunity may be of several types and may vary greatly in degree. Immunity which results from natural causes such as inheritance, or recovery from certain diseases like measles, scarlet fever, or diphtheria, is called *natural immunity.* Immunity which results from some specially designed process, like the injection of diphtheria toxin or antitoxin or emulsions of dead typhoid bacilli, or the Pasteur treatment for immunization against rabies, is called *artificial immunity.* These will be discussed in turn.

Natural Immunity.—This may be considered under three headings as follows:

1. *Species Immunity.*—It is quite evident that some species of animals have certain diseases which are peculiar to them and that they are immune to certain diseases which affect only animals of some other species. For example, the lower animals never have measles or typhoid fever in nature. Birds do not become infected with the kind of tubercle bacilli which infects cattle or human beings, while on the other hand human beings never become infected with the bird (avian) type of tubercle bacilli nor with fowl pox. None of the lower animals contract either syphilis or gonorrhea in nature, although certain of them may be infected by special laboratory inoculations.

Species immunity, especially in the case of birds and fish, is probably due largely to differences in body temperature, although chemical and physiological differences between the different animals also doubtless play a part. A micro-organism adapted to live and multiply in one species usually finds it difficult or impossible to adapt itself to life in another, finding there an unfavorable environment.

2. *Racial Immunity.*—It has long been known that there are differences in the susceptibility of different races to various diseases. An outstanding example of this was seen when white explorers first introduced tuberculosis among the inhabitants of isolated islands in the South Pacific. Tuberculosis in adult white people is usually (not always) a chronic disease which can be held in check, arrested, or even cured, if proper treatment is instituted early and continued for months or years. The South Sea brown race, however,

contracted the disease in an acute form when they first came into contact with the white race and died rapidly in large numbers.

Other racial differences in immunity are known. Certain races of white mice are almost entirely resistant to yellow fever, while others if properly inoculated succumb readily. White people are more susceptible to diphtheria than colored people in the Southern states, and Hebrews are more resistant to tuberculosis than other races.

The resistance of a certain race to certain diseases, such as tuberculosis or syphilis, may be due to the fact that the causative agent has long infected that race and both host (the infected animal) and parasite (the infecting organism) have become better adapted to each other. In this case, when the parasite gains entrance to the host, the process of invasion proceeds more slowly, a less acute reaction occurs, and the host does not appear so ill. This would suggest that in cases of prolonged contact with any disease, the more resistant individuals survive and pass their resistance on to succeeding generations. The nature of this resistance is not clear. This explanation however, probably does not hold in other instances, such as the difference in susceptibility of races of white mice to yellow fever. Mice which have come from cold countries where yellow fever does not exist exhibit the same differences.

3. *Individual Immunity.*—An individual may be resistant to certain diseases not only because of his species and his race, but also because of his general health and robust condition. This is largely a relative immunity and is entirely nonspecific; that is, it may

vary from day to day, and is an immunity not to any specific disease, but to disease in general. For example, a man in robust health may resist infection by pneumonia germs thrown into his face by a coughing patient. If, however, he becomes exhausted and weakened by starvation, cold, overwork, or some chronic disease, he may readily succumb to a variety of infections which he could easily resist if he were healthy. Tuberculosis is an excellent example of this type of infection.

Naturally Acquired Immunity.—An individual may become immune to certain infectious diseases by actually contracting them and recovering. This is spoken of as *active natural immunity* or *naturally acquired immunity.* It is entirely specific; that is, a person who recovers from diphtheria is immune to diphtheria (in nearly every case), but this does not prevent him from contracting typhoid or smallpox. The immunity is due to the presence in the body of substances called *antibodies.* Antibodies are probably protein molecules dissolved in the blood plasma. The body produces these as a part of its reaction or response to the presence of the invading bacteria or their poisons (toxins). In some diseases, the stimulus of the germs responsible for antibody production is so great that the body cells appear to continue to produce the substances long after the infection has disappeared, sometimes during the entire life of the patient. This results in a lifelong immunity to that particular disease. The antibodies can often be found in the blood by appropriate methods, some of which will be described later. Among diseases of this type are diphtheria, scarlet fever, typhoid fever, measles, mumps, smallpox, yellow fever, and some others. Pneumonia, common colds, erysipelas,

malaria, and some other diseases do not appear to stimulate prolonged antibody formation. Consequently second and third attacks of these diseases are not infrequent.

Subclinical Infections.—It may be pointed out that a person, in order to acquire an active immunity naturally against a specific disease, need not contract that disease in a severe (clinical) form. On the contrary, many persons develop immunity to such diseases as diphtheria and scarlet fever, and, in the tropics, to yellow fever, without ever being aware of any definite attack of illness. Their health or racial stock may have enabled them successfully to withstand the invaders to the extent that no severe illness occurred (subclinical or "silent" infection), yet the body cells were sufficiently stimulated to produce antibodies. On the other hand, the germs may have been somewhat less virulent than usual.

In the next chapter we shall have more to say concerning the various types of antibodies, the use of germs of reduced virulence in producing immunity artificially and of *antigens*.

CHAPTER VII

ANTIGENS AND ANTIBODIES

Antigens—Antibodies—(1) Antitoxins—(2) Amboceptors and complement: Cytolysins—Fixation of complement: the Wassermann reaction—(3) Other types of antibodies: precipitins; agglutinins.

Antigens.—Comparatively little is known about the chemical nature of the substances in the blood (antibodies) which help to combat disease. Nevertheless considerable has been learned of the way in which they are produced, their types, and their mode of action. We know, first of all, that some sort of stimulus to the body is necessary before it will produce antibodies against specific organisms or their poisons. The stimulus, it seems clear, is the presence in the body, of the actual organisms or their toxins. The body appears to be irritated or stimulated by this in some way, and responds with the production of antibodies which tend to act as "antidotes" to the poisons and to destroy the bacteria. The bacteria and their poisons therefore act as "antibody-engenderers" and have, for convenience, been designated *antigens*. *Any substance which stimulates the production of antibodies against itself when it gains entrance to the blood or tissues of the body is called an antigen.* It simplifies matters very much to remember that, with one or two exceptions, *the only substances which can act as antigens are proteins*, and that *if a substance is a protein, it can probably act as an antigen*, although it may not be

poisonous or of bacterial origin. Such substances as egg-white, serum, milk, snake venom, dead or living bacteria, plant tissues, the flesh of any animal, and a long list of other substances may all, when injected into the body, act as antigens.

Antibodies.—1. **Antitoxins.**—The type of antibody engendered depends on the antigen. For example, the plant, animal or bacterial toxins which are soluble in water (soluble toxins) engender antibodies which in some way neutralize them when they get into the blood, somewhat as an acid neutralizes an alkali. The neutralization reaction is not entirely understood. The antibodies engendered by the soluble toxins are called *antitoxins.* When diphtheria organisms gain a foothold in the throat and grow there, secreting their soluble toxin into the blood stream, the body responds by producing *diphtheria antitoxin.* The same thing occurs in the case of all other toxins, no matter how they gain entrance to the blood—by infection, by hypodermic injection, or by absorption through the skin or intestinal walls. *Each antigen,* however, *engenders antibodies only against itself and not against some other antigen.* For example, the poison of the cobra will engender antitoxin only against the cobra venom and not against the venom of any other kinds of snakes, diphtheria bacilli, or against measles virus. *Each antibody is strictly specific against its own antigen.*

2. **Amboceptors (Sensitizers) and Complement.**—There are thousands of different proteins which engender antibodies. Not all of them, however, are poisons and they engender not antitoxins but other types of antibodies. One of the best known of these other types are the antibodies called *amboceptors* or *sensitizers.*

Their action is possibly a little more complicated than that of the antitoxins.

Cytolysins.—A good illustration of amboceptor or sensitizer is the type called *cytolysins*, which are engendered by organized structures such as living cells (as contrasted with unorganized matter like soluble toxins, cobra venom, egg-white, and serum). The term cyto-lysin is derived from two words: the first, from which cyto is derived, means *cell* and the second, from which lysin is derived, means *to dissolve*. The cytolysins act, as their name indicates, to dissolve the cells which stimulated their production. In dissolving an organized antigen, such as typhoid bacilli or the red blood cells of some animal (Fig. 27), the amboceptor (ambo- *both;* cept- *to hold*) combines firmly with them.

Complement.—This simple combination, however, while absolutely essential, is not sufficient to complete the work of the cytolysin. A substance which is always present in the blood completes the work, and indeed, assists any and all amboceptors to complete their work. The amboceptors are specific in that they will combine only with their own antigen. The substance which completes their action is not specific. Since it acts to complete the reactions it is called *complement.*

Complement does not have to be engendered by any antigen but is always present in the blood from birth. No matter how many different specific cytolytic amboceptors are produced, the same nonspecific complement helps them all in their work. The amboceptors may be said to *sensitize* the antigens to the action of the complement, and that is why they are called by some scientists *sensitizers.*

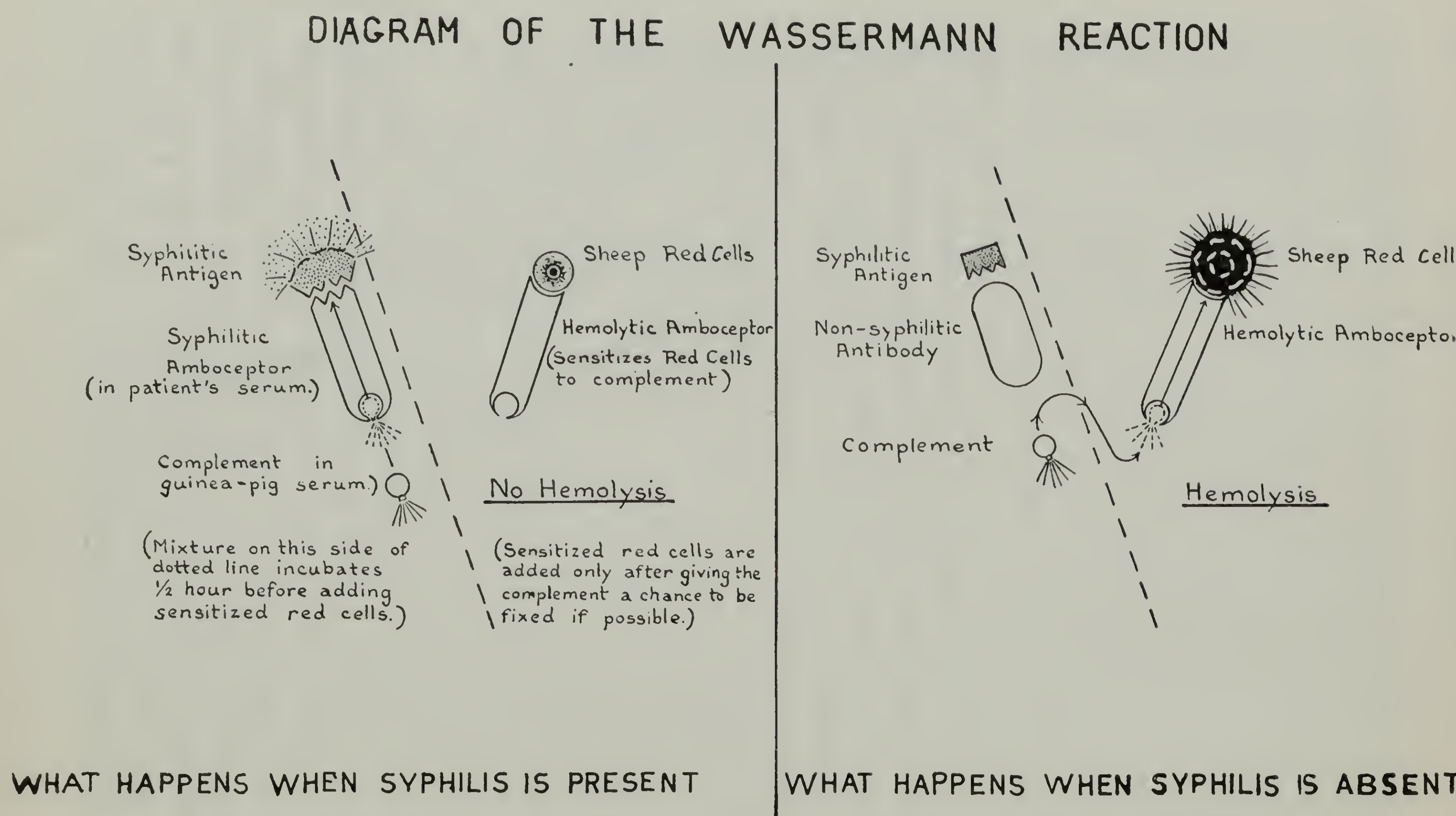


Fig. 27.—For explanation see text. A very common example of *fixation of complement.*

Fixation of Complement.—When complement completes the reaction between antigen and antibody, it combines with them in some way and is apparently used up or "fixed." "*Complement fixation*" is said to have occurred. The student will hear a great deal of complement fixation, which is sometimes called the phenomenon of Bordet and Gengou, after the two Belgian scientists who discovered it.

The Wassermann test is discussed as an outstanding illustration of complement fixation. A scientist named Wassermann showed in 1906 that the organisms of syphilis, when in the human body, engendered amboceptors which would, as usual, "fix" complement when combined with their antigens, the syphilis organisms. He therefore devised the test (Fig. 27) which bears his name and is used to discover whether a person has syphilis. The serum of the patient, which contains the syphilis amboceptor, is mixed in a test tube with a little of the syphilis antigen. The usual combination occurs and some or all of the complement in the serum is used up, or "fixed." *The difficulty is in knowing whether the complement is fixed or not,* since all of the substances and the reaction itself are quite invisible, and one cannot see what is going on in the test tube. One must test the mixture to see whether there is any unfixed or free complement which could complete some other reaction if it had the opportunity. *A very simple test is to add a few red blood corpuscles which are already sensitized to complement with a specific amboceptor prepared for them.* If there is any free or unfixed complement, it will combine with the red corpuscle-amboceptor complex and dissolve the corpuscles. One can easily see if the red corpuscles have

been dissolved, because the suspension of cells becomes clear and ruby-red, whereas previously it was cloudy-red (Fig. 28).

This simple test is used in every hospital. Since Wassermann's original test a few modifications have been adopted. It was found that the actual organisms of syphilis were not entirely necessary as antigen, but that certain substances which could be extracted with alcohol from normal heart tissue would serve as well or better. These alcoholic antigens are used in all modern laboratories in doing the Wassermann test. Furthermore, it was found that the amount of complement present in the patient's serum varied a great deal, and especially that it degenerated after a few hours and consequently would not react well when tested for with the sensitized red corpuscles. Therefore it is now the custom to destroy entirely the varying amounts of complement already in the patient's serum by gentle heating (*inactivation*) and substitute a standard, carefully measured (or titrated) amount of complement from some other source, such as the serum of guinea pigs. This also enables the person doing the test to form some opinion as to how much complement remains free, since he knows how much he added originally. If part of it has been fixed, some of the sensitized red corpuscles will fail to be dissolved or *hemolysed* (Fig. 28). *When all the cells are hemolysed, it indicates that none of the complement was fixed by the patient's serum* in contact with the syphilis antigen. *It is then known that the patient did not have syphilis amboceptor in his serum.*

The Wassermann test is subject to a number of sources of error if not done carefully, but these do

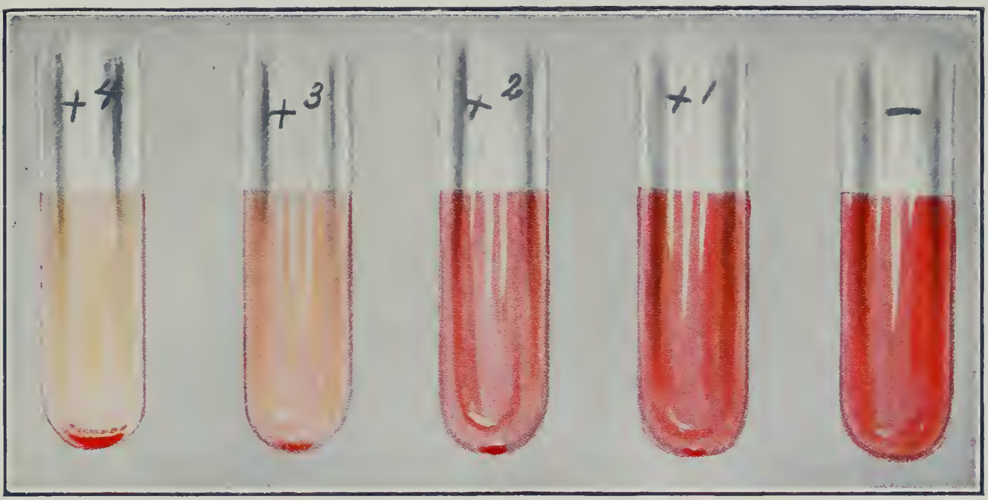


Fig. 28.—The first tube shows a strongly positive (plus 4) Wassermann reaction. All the red cells remain intact and have sunk to the bottom, leaving the fluid clear. The second tube shows a "plus three" reaction. Although most of the corpuscles remain uninjured and have settled, enough have been dissolved to give the fluid a slightly red tinge. The next two tubes show weakly positive reactions, *i. e.*, increasing amounts of red cells have been destroyed and the fluid takes on a deeper red color. The last tube shows a completely negative reaction; *i. e.*, all the corpuscles have been hemolysed, and consequently the fluid is colored ruby red and there is no sediment. (From Kolmer "Infection, Immunity and Specific Therapy.)

not concern us here. The student who is interested may gain more detailed information by visiting the Wassermann technician in her hospital or by reading one of the larger textbooks on immunology or medical bacteriology.

3. **Other Types of Antibodies.**—In addition to antitoxins, cytolytic amboceptors and complement, there are other types of antibodies. Some of these combine with the specific bacteria or soluble proteins which engendered them and, in the presence of the mineral salts in the blood, cause the bacteria or other proteins to gather in clumps. Those which act in this way against unorganized protein molecules are called *precipitins*, and those which act against bacteria, *agglutinins*. These reactions are *specific*.

Precipitin reactions are used practically to distinguish the bloods of different animal species; thus, in *legal medicine* to determine whether a blood stain is of human or animal origin. If it is human blood, a solution made from it by washing with normal saline will give a precipitate with the serum of an animal immunized with repeated doses of human red corpuscles. The reaction is very delicate and is positive even after the stain has dried for many years. If the blood spot has come from other than human sources, it will not give a precipitate with the immune serum.

The Kahn test for syphilis (Chapter XXIII, Fig. 81) is a precipitin reaction.

Agglutinins.—These can be stimulated by various kinds of cells; those which have the greatest practical importance are the bacteria and the red corpuscles.

A number of useful diagnostic tests are based on bacterial agglutinins. For example, if a person has

typhoid fever, his blood will be found to contain agglutinins against typhoid bacilli. By mixing a little of

Fig. 29.—Agglutination of bacteria by immune serum in dilutions of 1/10, 1/20, 1/50, and 1/100 (*i. e.*, 1 part serum and 9 parts normal saline, etc.). The first tube is a control containing the bacteria in a 1/20 dilution of normal serum. Some of the organisms have settled to the bottom through the action of gravity, but enough remain suspended to render the fluid opaque. The immune serum agglutinates the bacteria completely in the middle tubes. The organisms have clumped and fallen to the bottom, leaving the fluid clear. The 1/200 dilution of immune serum in the last tube is too weak to agglutinate the bacteria. (From Hiss, Zinsser and Russell "Text-Book of Bacteriology," D. Appleton & Co., Publishers.)

his serum with a culture or suspension of typhoid bacilli, the action of these agglutinins can be observed, since, after a short time, all the bacilli, evenly distributed

throughout the culture at first, become gathered together into fairly large clumps and flocs and settle to the bottom of the test tube, leaving the suspending fluid clear (Fig. 29). The reaction can also be observed with the microscope (Fig. 53).

Diagnosis of various infections can be made in this way: if a patient's serum agglutinates a certain germ, then he probably has or has had an infection with that organism, or he has been artificially immunized to it. Sometimes a person's serum gives an agglutination reaction, not because he has an infection at present, but because he has received injections (vaccine) of the organism which his serum agglutinates, or because he may previously have had an infection with the organism and recovered. This will be discussed in the next chapter.

It is believed that agglutinins do not actually kill the bacteria which they agglutinate. The exact mechanism of the action is very complicated and there are a number of theories concerning it.

Agglutinins aid in the removal of cellular proteins by leukocytes, since a leucocyte or other phagocytic cell can as easily engulf fifty agglutinated bacteria or protein molecules as a single one, and fifty times as quickly!

As to the agglutination of red cells, it is necessary to say here only that human bloods are divided into four groups on the basis of their tendency to form agglutinins against one another. A test is therefore made before transfusion in order to be sure that the patient's serum will not agglutinate the donor's corpuscles. The nurse will learn more of this in her study of blood transfusion.

CHAPTER VIII

ARTIFICIAL IMMUNITY

Artificial immunity: types—*Active artificial immunity*—(*A*) By injections of living attenuated organisms: vaccination against smallpox; Pasteur treatment for rabies; Calmette antituberculosis treatment —(*B*) By injections of dead organisms: bacterins—(*C*) By injection of toxins—Rate of antibody production—*Passive immunity*—Preparation of antitoxic sera—Serum sickness—Passive immunity in the prevention of disease.

Artificial Immunity.—Immunity, as we have seen, may result from a number of natural causes. Some of these result in specific resistance (resistance to a single, specific disease), and others in a general, nonspecific resistance. Man has attempted to imitate and help nature by devising ways to develop resistance artificially and safely. The means used are really natural processes modified and controlled. There are two types of artificial immunity: *active artificial immunity* and *passive immunity.* We shall discuss the active immunity first.

Active Artificial Immunity.—(A) **By Injection of Living Attenuated Organisms.**—This may be produced in one way by imitating nature's method of mild or inapparent infection. Live germs are actually injected or otherwise put into the body, but the germs are weakened or attenuated by various processes so that they cannot cause a severe infection. Probably the best illustration of this type of immunization is vaccination against smallpox.

1. **Vaccination against Smallpox.**—The *principle* of this procedure is quite complicated, but it may be stated in a general way as follows: the organism which causes smallpox in human beings also produces in cows a mild disease called cowpox, which appears as an eruption on the udder. In some way which is not understood, smallpox, when inoculated into cows, changes its character and becomes a mild disease. When the organisms of this disease are transmitted back again to man, as is done in vaccination, they cause, not smallpox but the mild, non-contagious condition seen in vaccination. This is, however, sufficient to give protection from smallpox for a number of years. The relationship between cowpox and smallpox, and the fact that inoculation with matter from the eruption of cowpox would protect against a later inoculation with the virus of smallpox, were demonstrated by *Edward Jenner*, an English county doctor. He published his observations in 1798, after he had been studying and experimenting on the subject for twenty years. Jenner noted that persons working around cows which had cowpox developed sores on their fingers like those on the cow's udders, and that these persons never caught smallpox during an epidemic. He introduced on a large scale the practice of inoculating people with the material from the eruption of cowpox, which, in an improved form, is what we now call vaccination. To Jenner, therefore, belongs the credit of giving vaccination to the world. Jenner checked his procedures by scientific methods and experiments. His work was *one of the greatest discoveries in medicine.* Vaccination is now a simple preventive measure within the reach of all. It

is taken so for granted nowadays that we are in danger of forgetting how valuable is the protection. Without it, smallpox would be just as frequent and virulent as it ever was.

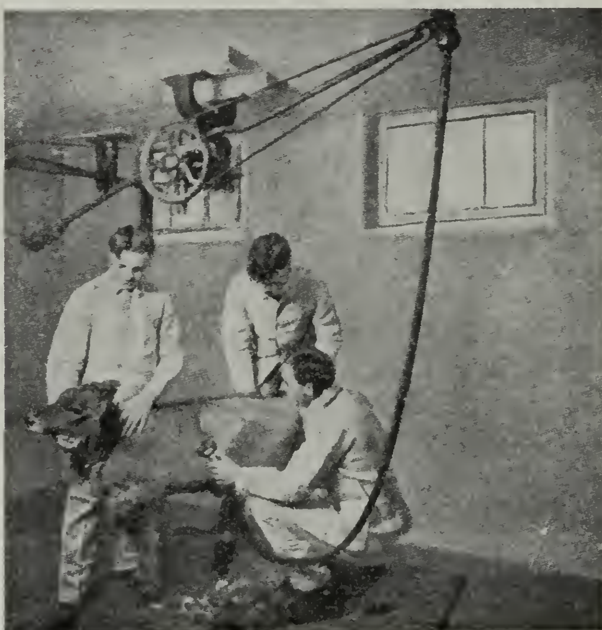


Fig. 30.—Preparing a calf for vaccination. The animal is washed, the long hair clipped, and the skin scrubbed with bichloride solution. The antiseptic is removed with sterile water and the surface to be operated on is shaved. (Courtesy of H. K. Mulford Company, Philadelphia.)

Vaccination (vacca = Latin for cow) is thus the transference of the virus from the skin eruption of an animal having cowpox into the skin of a human being, for the purpose of preventing smallpox. It is an active immunity produced by the introduction of living organisms. It is therefore entirely different in principle from immunization with bacterial vaccines, in which the organisms injected have been killed, or immunization with sera, in which no organisms are injected but the blood serum

of an immunized animal. These methods are discussed later.

Vaccine virus is prepared by innoculating perfectly healthy calves with living organisms either from an animal previously inoculated with vaccine virus or from a human vaccination sore. The skin of the abdomen and inner side of the thighs is shaved (see Fig. 30)

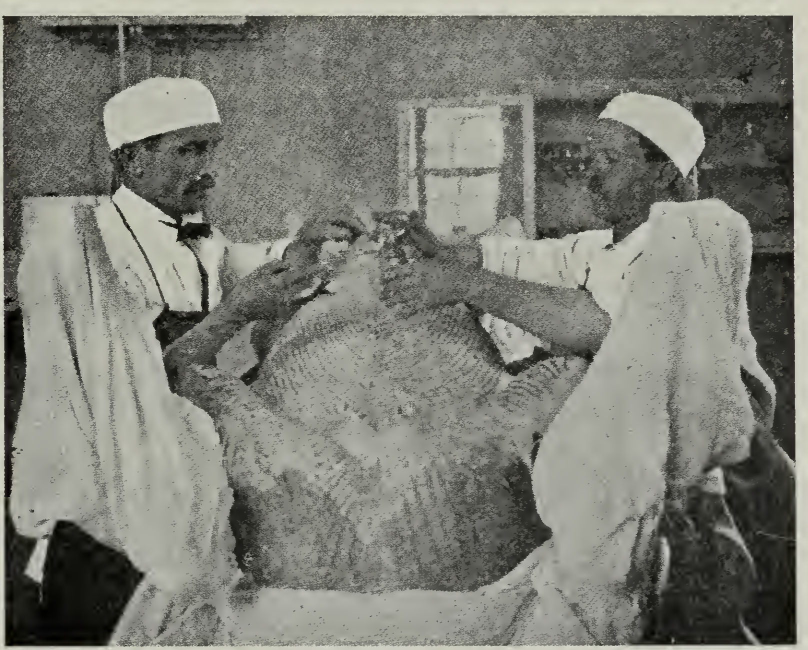


Fig. 31.—Removing the virus from the lines of the vaccination eruption. (Courtesy of Parke, Davis & Company, Detroit.)

and sterilized, and slight scratches are made in parallel lines over this area. The virus is rubbed into these scratches, after which the skin is dressed with sterile gauze and cared for with aseptic precautions. In a few days the calf develops sores similar to those following vaccination in human beings. The material from these is scraped out and worked up with glycerin (see Fig. 31). One calf yields enough virus to vaccinate 1500 persons. Freshly prepared vaccine always con-

tains bacteria. It is therefore allowed to stand for three or four weeks, by which time the gylcerin has usually killed all the bacteria. It is not put into tubes, however, until it has been tested and found to contain no bacteria. Recently it has been found that the bacteria can be removed by filtration and this method will probably be more widely used in the future. The

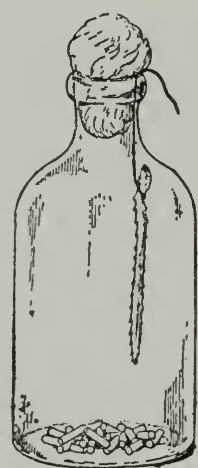


Fig. 32.—Method of drying the spinal cord of a rabbit dead of rabies, for the purpose of attenuating the virus. The cord is removed from the animal with aseptic technic, and suspended by a sterile thread in a bottle over pieces of potassium hydroxide. This substance has a great power of absorbing moisture. (From Hiss, Zinsser and Russell "Text-Book of Bacteriology," D. Appleton & Co., Publishers.)

virus is also tested for its vaccination power by animal experimentation. A single dose of virus is put up in a small tube, which is washed with alcohol before use, broken with sterile gauze, and emptied by means of a small rubber bulb. The virus must be kept cold until it is used.

2. **Pasteur Treatment for Rabies.**—This depends on a principle very similar to that of vaccination against smallpox. In order to attenuate the rabies virus, it is dried. The organism causing rabies is still imper-

fectly known. We do know, however, that it localizes in the brain and spinal cord and that the disease may be transmitted by injections of the fresh brain or spinal cord of an animal dead of rabies.

If, however, the brain or cord be allowed to dry out partly (Fig. 32), the organism is so weakened that, although it cannot cause the disease, it may still stimulate the production of antibodies.

The Pasteur treatment for rabies consists of a series of injections of partly dried spinal cord of rabbits dead of rabies. It is a great boon to mankind, since rabies was formerly a prevalent and much dreaded disease (Chapter XXVI).

Recently experiments have been tried in which dead, instead of merely weakened, organisms have been used to immunize to rabies. There is evidence that such a method may be better than the older one devised by Pasteur.

3. **Calmette Antituberculosis Treatment.**—Recently an attempt has been made to introduce, as a preventive measure against tuberculosis, injections of living but weakened tubercle bacilli. Calmette, a French scientist, introduced this method and a very wide study and trial of it has been made. The material injected consists of cultures of tubercle bacilli grown in a special medium containing bile, which is supposed to lower the virulence of the germs. It is called B.C.G. (Bacillus Calmette-Guérin) Vaccine. As yet it has not received wide acceptance in America, too great a doubt existing in the minds of some physicians that the virulence of the bacilli is really permanently lowered by the medium used. This will be discussed further under Tuberculosis.

(B) By Injections of Dead Organisms: Bacterins.—A second method of producing active artificial immunity is very similar to those just described. The actual germs causing the disease are injected into the body, and the body reacts as usual, by producing antibodies. In the particular procedure under discussion, however, the germs, instead of being weakened, are dead, having been heated, or killed with some chemical disinfectant. Such preparations of killed bacteria are properly spoken of as *bacterins*, but are more frequently called *bacterial vaccines* or simply *vaccines*. The term vaccine can from its derivation be properly applied only to the cowpox material used for immunization against smallpox.

Many types of bacterins are used. The commonest is the so called "typhoid vaccine," which is prepared by cultivating typhoid bacilli on large agar plates. The fresh young growth is washed from the plates with physiological salt solution, and the suspension of bacilli thus obtained is heated at a temperature of about 60 C. for about one hour. In some laboratories, the bacilli are killed with formaldehyde instead of heat. The suspension is then diluted to a suitable concentration, a small amount of disinfectant is sometimes added as an additional precaution, and the bacterin is put up in ampoules and is then ready for injection. It is customary to give three successive injections of this vaccine at intervals of about a week. Similar vaccines are prepared with the bacteria which cause boils (staphylococci), and a number of others.

Mixed Vaccines.—Sometimes several kinds of bacteria are mixed together in a single suspension. This is usually done with typhoid vaccines, the preparation sold on the market containing also dead

paratyphoid bacilli of two types. In some countries dysentery bacilli and the germs of cholera are often included. Such vaccines, containing *more than one kind of organism*, are spoken of as mixed vaccines.

Polyvalent Vaccines.—Sometimes a vaccine is prepared using several races or varieties of a single type of organism. For example, there are at least a dozen different races or types of gonococci which differ from each other slightly but definitely. It is customary, when preparing gonococcus vaccine, to include these various types so as to be sure to induce the production by the patient of antibodies against the particular type of gonococci with which he may be infected. Such a vaccine, containing *different races or types of the same organism* is called a polyvalent vaccine.

Autogenous Vaccines.—In treating some diseases, especially furunculosis (boils), it has been found better to use a vaccine made of bacteria cultivated directly from the patient. In this way one is sure of obtaining the type of organism actually infecting the patient, and of inducing appropriate antibodies when the vaccine is injected into him. Such a vaccine, produced with *germs from the patient himself*, is called an autogenous vaccine.

Sensitized Vaccines.—Sometimes organisms intended for use in a vaccine are *treated, before injection, with the complement-free serum of a person or animal who is immune to those bacteria.* The germs combine with the amboceptors or sensitizers in the serum so that they are *acted upon readily and quickly by the complement of the person into whom they are injected* and immunize more rapidly and advantageously. Such a vaccine is called a sensitized vaccine.

(C) Active Artificial Immunity Produced with Toxins. A third method of producing active immunity artificially differs from the two preceding methods in that no organisms, alive or dead, come into contact with the body. As we have pointed out, the antibody produced depends on the type of antigen used. In certain diseases, for example diphtheria and scarlet fever, the damage is largely due, not to the bacteria themselves, but to the toxins which they give off into the blood. These toxins engender antibodies (antitoxins) very readily. Therefore, if a person receives carefully controlled injections of small amounts of toxin, he will soon be able to withstand large doses of the toxin injected. His body develops antitoxins just as if he had the disease naturally.

This phenomenon is used in immunizing people, particularly children, against diphtheria and scarlet fever. The actual process and materials used in producing active immunity against these diseases will be discussed in the sections dealing with them.

Rate of Antibody Production.—It may be pointed out that the production of antibodies by the person receiving any injections of vaccines or toxins is relatively slow, requiring six to ten weeks for its completion, so that the injections must be commenced a reasonable time before a person is liable to be exposed as, for example, by starting school, or in any other way. There are, however, methods of developing immunity to some diseases immediately. These are discussed in the section to follow.

Passive Immunity.—The reader has learned that the presence of any antigen, toxic or nontoxic, in the blood or tissues results in the production of antibodies. This

occurs whether the antigens gain entrance to the body naturally, as in disease, or artificially as when injected with a syringe. It has been pointed out that the response of the body to such antigens is comparatively slow, requiring weeks or months before effective amounts of antibodies appear in the blood.

In some cases, it is highly necessary that a large supply of antibodies appear in the blood immediately

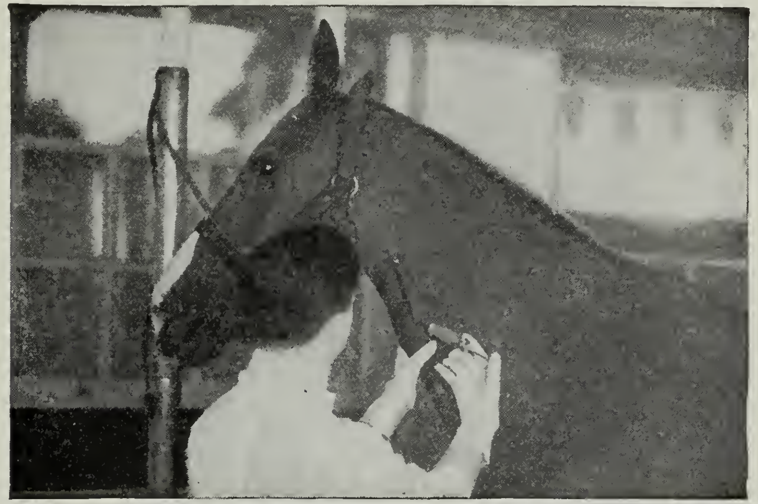


Fig. 33.—Injection of diphtheria toxin (broth in which diphtheria bacilli have grown) into the jugular vein of a horse. Observe that the horse is not being hurt. (Courtesy of H. K. Mulford Company, Philadelphia.)

in order to combat an overwhelming amount of antigen. This is especially well illustrated in such diseases as diphtheria, tetanus, and scarlet fever. The chief symptoms in these diseases are caused by the presence of the bacterial toxins in the body of the patient, and their unfavorable action is very rapid. The patient is too ill and there is no time to lose waiting for him to develop an active immunity. He must passively receive ready-made antibodies. Immunity resulting

from injections of these ready-made antibodies, is called *passive immunity*.

It is now possible to purchase, at all well stocked pharmacies and health departments, syringes or ampoules already filled with antitoxic serum prepared for just such emergencies. Such antitoxin-containing

Fig. 34.—Bleeding from the jugular vein a horse that has been injected with diphtheria toxin. The blood contains diphtheria antitoxin. Note the aseptic technic. The site of the operation has been shaved and treated with antiseptics. As much care is exercised to avoid infection as in operations on human beings. (Courtesy of H. K. Mulford Company, Philadelphia.)

serum is obtained from animals, usually horses, which, weeks or months previously, have received repeated injections of the special toxin against which an antitoxin is desired.

Preparation of Antitoxic Sera.—The most widely used sera are those against the diphtheria and tetanus

bacilli, meningococci (the cause of cerebrospinal fever), scarlet fever streptococci, and pneumococci. Innumerable lives have been saved by the use of diphtheria, tetanus, and meningococcus sera.

At the present time scientists are making great advances in preparing and improving sera against other infections, and the use of this form of treatment will undoubtedly become more general in the future.

The usual method of making therapeutic sera is as follows: A horse is injected subcutaneously, at intervals of five to seven days, with gradually increasing amounts of broth in which the desired germs have grown, and which contains their toxin (Fig. 25). The horse is the animal chosen because on account of its size it yields a large amount of blood. The first dose is very small, not enough to make the animal sick; but at the end of the treatment it may take, without symptoms, many times what would have been a fatal dose at the beginning. At the end of three or four months, when the horse has developed a large amount of antitoxin in its blood, it is bled with aseptic precautions from the jugular vein, six to eight quarts of blood being removed at one time (Fig. 34). The blood-serum separates from the clot on standing and contains the "antitoxin" used in medical practice (Fig. 35). The horse is given further treatment at intervals, and is bled about once a month as long as it continues to furnish a high grade of antitoxin, which period varies from six months to several years. The horses which are used for the production of curative sera are kept under the best hygienic conditions and remain well and comfortable throughout the treatment.

Sera must be kept in a dark, cool place, as they gradually lose their strength when exposed to light and

warmth. Under good conditions they may keep their strength for as long as a year.

Injections of such sera *before the toxins in the patient have done too much damage* practically always result in an improvement of condition and usually a cure. It is *extremely important* to remember that *antitoxic sera will stop the damaging process, but will not repair damage already done.* Sera given very late in the disease are practically without effect and may then do harm.

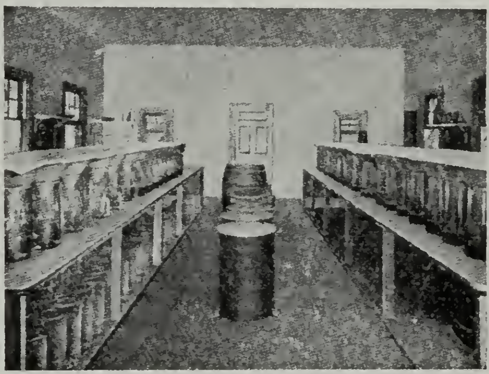


Fig. 35.—A laboratory in which the serum containing antitoxin is refined and concentrated. The material in the glass jars is serum in various stages of preparation. (Courtesy of H. K. Mulford Company, Philadelphia.)

Serum Sickness.—Sometimes a patient will react in an undesirable way against the proteins in the antitoxic serum. *The reaction is due to the animal proteins and not to the antitoxin.* The patient may have a chill, nausea, and sometimes very alarming symptoms. They are all due to a peculiar condition related to *allergy* or *hypersensitiveness* which is discussed in the next chapter. These reactions, while undesirable, seldom end unfavorably unless, as has just been pointed out, the patient is in a very late stage of his disease and a much weakened condition. The reactions are called *serum sickness* or "*protein reactions.*"

It is possible to prevent or greatly reduce the protein reactions by giving a number of tiny doses of the serum at intervals of an hour or so before the main injection. The possible shock to the patient is materially lessened. The process is spoken of as *desensitization* of the patient.

In order to reduce the number and severity of such protein reactions, processes have been devised to remove as much of the nonspecific serum proteins and leave as much of the antitoxin as possible. Such purified material is called *concentrated* or *purified antitoxin.* It is much superior to the unconcentrated serum and is what is now generally sold as antitoxin.

In the United States the production and sale of therapeutical sera, bacterins, smallpox vaccine, and other biological products are regulated by law. The establishments in which they are manufactured are licensed, and samples of the products are tested at the Laboratory of the National Institute of Health at Washington. Products which do not come up to the standards set for them are not allowed to be sold.

Passive Immunity in the Prevention of Disease.—Passive immunity is used in the prevention as well as in the cure of disease. For example, if it is known or suspected that a person is likely soon to become exposed or has recently been exposed to diphtheria, scarlet fever, tetanus, epidemic meningitis, yellow fever, measles, infantile paralysis, (anterior poliomyelitis) and some other diseases, it is an excellent plan as a precaution to inject a small quantity of serum containing the appropriate antibodies.

The antibodies in all passive immunity disappear from the body in a few days or hours, but while they are

present they may entirely prevent an infection or greatly lessen its severity.

It is a routine measure in most hospital accident wards to inject tetanus antitoxin in order to prevent the development of this disease in persons injured in street accidents. This is because in all street accidents, dirt containing spores of tetanus bacilli gets into the wound. This will be discussed later. Very young children, in whom measles is a dangerous disease, often receive the serum of some child who has recently recovered from measles, in order to ward off the disease until they are older and can better withstand the infection. The same precautions may be taken to prevent temporarily poliomyelitis (infantile paralysis) and chicken pox. Usually it is done during epidemics or times of special danger, or just before long journeys.

CHAPTER IX

HYPERSENSITIVENESS

Allergy and anaphylaxis—Pollen, food, and bacterial allergy—Serum reactions—Skin tests for hypersensitiveness.

Allergy and Anaphylaxis.—We have pointed out that when a protein is injected into a human being or an animal of any sort, antibodies of one type or another are developed against that particular protein. The animal is said to have been *immunized* against that protein. In spite of the fact that the animal is immunized to the protein, it does not necessarily follow, strange as this may seem, that the protein will no longer harm him. Still stranger, and apparently absolutely contrary to previous teachings, a protein like eggwhite, entirely harmless when injected the first time, often produces very severe and sometimes fatal reactions in such animals as guinea pigs or rabbits if injected a second time *about two weeks later.* The reactions are characterized by a lowered body temperature, difficult breathing, weakness, and finally convulsions. As guinea pigs show this phenomenon with particular violence, they are generally used in the laboratory to demonstrate this reaction, which is called an *anaphylactic* (ana = *against*, phylaxis = *protection*) reaction. *If a second dose of the protein is given before the end of the two-week period—the so-called "refractory period"—no anaphylactic reaction is produced.*

In addition to producing antibodies, the first injection seems to *sensitize* certain cells of the animal's body to

the second dose, producing a condition of extreme reactivity. The animal is said to be in a *hypersensitive* or *allergic* (from the Greek: allos = *change*, and ergon = *action*) state to the protein.

The first injection is often called the *sensitizing dose.* The second injection, because of the reaction it produces, is called the *toxic dose.* If the hypersensitive animal survives the second injection, the toxic dose, he is then no longer sensitive but is really immune. He is said to have been *desensitized* by the second inoculation, and can then safely receive large injections of the protein at any time.

Any foreign protein, harmless or harmful, gaining entrance to the body, may set up a condition of hypersensitiveness. The condition is therefore often spoken of in a general way as *protein sensitization.* It can be caused by a great variety of substances—bacteria, foreign sera, dandruff, feathers, pollen, and various foods. The hypersensitiveness manifests itself, however, in different ways. Much depends on the route by which the protein gains entrance to the body, the kind of protein, and especially the kind of animal. The violent type of reaction seen in guinea pigs very seldom occurs in man.

A condition of hypersensitiveness appears to be a step in the development of immunity, as will be discussed in connection with tuberculosis. Certain phases of it, however, as seen in serum sickness, and pollen and food allergy, give rise to unpleasant symptoms. In other relations, the hypersensitive condition is used as a basis for diagnostic tests.

Pollen Allergy.—The pollen (sperm cells) of certain plants, among them ragweed, grasses, roses, and golden

rod, are capable of producing allergy in some persons. The protein of which the pollen cells are composed, landing on the nasal and respiratory mucosa of many persons, appears to set up a hypersensitive condition of these tissues so that when the person later on inhales more of the same pollen his nose and throat become irritated, swollen, and edematous, and all the symptoms of a severe "cold" may develop, due to the severity of the reaction against the pollen. This condition is very well known and is commonly called "*hay fever.*" A person may be desensitized by receiving a series of injections of the proper pollen.

Food Allergy.—In the same way, a person may be sensitized to a certain food, for example strawberries or codfish. If for some reason, such as a slight gastro-intestinal irritation, lesion, or disturbance, some of the protein of the food gets past the stomach or intestinal wall into the blood in an undigested condition, the result is the same as if the protein had been injected. The next time, and perhaps every time the person eats strawberries or codfish, he will react more or less violently. Usually under these circumstances the anaphylactic reaction manifests itself in the form of a rash or blotches on the skin which itch persistently. These are commonly known as "*hives.*" In other cases, the victim may become violently ill and exhibit nausea, vomiting, gastro-intestinal irritation, and perhaps general symptoms. The person may be desensitized, as in pollen hypersensitiveness, by receiving one or more injections of the protein of the appropriate food.

Bacterial Allergy.—Bacteria entering the blood stream may sensitize certain cells of the body to their protein. A very complicated set of reactions occurs

which may cause a variety of symptoms. For example, the rash of scarlet fever is thought by some to be a manifestation of hypersensitiveness. A person who has been infected with the tubercle bacillus remains in an allergic condition to the organism (Fig. 72), a most important consideration, as will be discussed later, in regard to his resistance to the disease. Allergy plays an important part in infectious diseases. In general, whenever an infectious disease becomes subacute or chronic, the body cells may become sensitized to the bacterial protein. The reaction following the later injections of a bacterial vaccine are in part an expression of a sensitized condition.

Serum Reactions.—These occur in two forms: the *acute* and serious form, accompanied by collapse and dyspnea, and coming on a few minutes after the injection; and the milder, delayed form, known as "*serum sickness*," which has been described in the preceding chapter. As these reactions are most liable to occur in patients who have asthma or pulmonary inflammation, investigation is made on this point. If the serum is to be given intravenously, a preliminary skin test for hypersensitiveness to horse serum may be made, as described below. If the test is positive, the patient is *desensitized*, as previously described, by giving very small preliminary doses of the serum.

Skin Tests for Hypersensitiveness.—The skin of a person or an animal hypersensitive to a certain protein will show a large, red, swollen area after an interval of a few minutes to a number of hours when a small quantity of the correct protein has been scratched or injected into it. This phenomenon is simply another manifestation of an allergic condition, but it is extremely

useful in determining what protein is causing a given patient's trouble.

In tests for food or pollen sensitiveness, alcoholic extracts of various foods or pollens which would be likely to be involved, are introduced into (not under) the skin either by scarification or injection, and the results observed. A number of probable substances are usually tested for at the same time.

The most widely used test for bacterial allergy is that for tuberculosis, the *tuberculin test* (Fig. 72), which will be described later.

All the various manifestations of hypersensitiveness described in this chapter are included in the general term Allergy. The explanation of just why or how the reactions occur is extremely complicated, and indeed, not well understood. The systematic study of allergy is more recent than that of some other aspects of immunology, and the subject is still involved in controversy. It is, however, assuming increasing importance in medicine, and in her clinical work the student will learn more of its diverse manifestations and practical applications.

CHAPTER X

TRANSMISSION OF DISEASE

How bacteria are cast off from the body—How bacteria are carried from one person to another—Contact infection—Indirect infection—Transmission of disease by insects—Human carriers—Disinfection in infectious diseases—Practical applications to nursing.

How Bacteria Are Cast Off from the Body.—There are certain definite pathways, as we have seen, by which germs enter the body. There are also definite ways in which they leave the body. They are cast off in the *excretions* and *secretions*, the most important of which in this connection are the feces, urine, sputum, nasal discharge, saliva, pus, and discharges from ulcers, wounds, sores, infected eyes, and other inflammatory conditions. The particular excretion in which the bacteria causing the infection appear depends on the disease. In diseases affecting the intestines, as typhoid fever and dysentery, they are present in the bowel movements. The urine contains bacteria in infections of the kidneys and bladder; also in some other diseases, notably typhoid fever. In infections of the lungs—for example, tuberculosis, pneumonia, whooping cough, and influenza—the sputum contains the organisms causing the conditions, sometimes hundreds of millions being thrown off in a single day. The saliva is infectious in diseases of the throat also, as tonsillitis and diphtheria. The nasal secretion contains the disease organisms in common colds, grippe, measles, and many other infections, and it usually also contains

germs from the lungs and throat. It is very important for the nurse to know the particular way in which the germs are cast off in each infection, so as to guard against spreading the disease through the discharges.

How Bacteria Are Transferred from One Person to Another.—Most disease-producing organisms die rapidly in the outside world, and multiplication outside the body occurs only in the case of a few, such as the growth of typhoid or diphtheria bacilli in milk. Disease germs, therefore, pass from one person to another either directly or with only a short stay outside the body. The most important way in which infection is transmitted is by directly touching the excretions of the infected person, or indirectly by touching things recently contaminated with them. For example, the germs of diphtheria, tonsillitis, or a common cold may be transferred *directly* from one person to another by kissing on the lips. Syphilis and gonorrhea are examples of diseases commonly transmitted by direct contact with an infected person. They may also be transmitted *indirectly* by any article soiled with the excretions which goes within a short space of time from an infected to a normal person. A nurse may get typhoid fever or dysentery by soiling her hands with the bowel movements of a patient and neglecting to scrub them before going to her meals, the bacilli being transferred *directly* from patient to nurse. A medical student may through imperfect technic infect himself directly from laboratory cultures.

If the typhoid bacilli get into a water supply, a single patient may *indirectly*, through the water supply, be the cause of hundreds of cases in a city a long distance away. Many other examples of ways in which bacteria

may be carried from person to person, either directly or indirectly, will occur to every one. If the sputum of a pneumonia or tuberculosis patient is allowed to dry, the germs causing these diseases may be blown into the air and spread around. Only a few bacteria have the power of motion, and that only in liquids, and *no bacteria can rise from a moist surface.* They are merely carried passively from one person or thing to another. Even when the method by which an infection is spread seems almost impossible to explain some unsuspected point of actual contact always will be found.

Contact Infection.—Genuine contact infection occurs only when one comes into *direct personal contact* with an infected person. Examples of this are infection transmitted by kissing, handshaking, and sexual intercourse.

Droplet infection, in which the bacteria are thrown out in coughing and sneezing, is a special form of contact infection, as the organisms pass directly from one person to another. When a person coughs or sneezes "into the open," bacteria are thrown into the air for two or three feet in droplets of saliva and mucus. These droplets are so light that they may remain in the air for a considerable time, and *they may be blown many feet by drafts.* This is undoubtedly an important way of spreading the organisms of colds, influenza, pneumonia, whooping-cough, tuberculosis, scarlet fever, diphtheria, and measles. Aside from the two special conditions: first, of dust carrying the dried and pulverized secretions of patients, and second, of spray from coughing or sneezing, the organisms in the air can be disregarded from the standpoint of disease.

Indirect Infection.—*Objects which are likely to carry disease* organisms are those which have recently come

into close contact with an infected person, as bed and body linen, handkerchiefs, drinking cups, tableware, and toys. Things which have not been in contact with the patient, such as floors, walls, furniture, and curtains, are unlikely to be the means of transmitting disease germs, unless they are covered with infective dust. In the control of infectious diseases we are growing more and more particular in the care of the patient's discharges and paying less attention to his surroundings.

We are all very careless in our habits in regard to saliva, far more so than we like to realize. The case has been stated vividly by a physician: "If infection by contact is of such very great importance in the fecal-borne diseases, how much more important must it be in diseases in which the infective agent is found in the secretions of the nose and mouth, as is the case with diphtheria, scarlet fever, small-pox, mumps, measles, whooping-cough, tuberculosis, influenza, and cerebro-spinal meningitis. Every one avoids feces and urine, but it is only the very few who have any objection to saliva.

"Not only is the saliva made use of for a great variety of purposes, and numberless articles are for one reason or another placed in the mouth, but for no reason whatever, and all unconsciously, the fingers are with great frequency raised to the lips or to the nose. Who can doubt that if the salivary glands secreted indigo the fingers would not continually be stained a deep blue, and who can doubt that if the nasal and oral secretions contained the germs of disease, these germs would not be almost as constantly found upon the fingers? In this universal trade in human saliva the fingers not only bring the secretions of others to the mouth of their

owner, but there, exchanging it for his own, distribute the latter to everything that the hand touches. This happens not once, but scores and hundreds of times during the day's round of the individual. The cook spreads his saliva on the muffins and rolls; the waitress infects the glasses and spoons; the moistened fingers of the peddler arrange his fruit; the reader moistens the pages of his book; the conductor his transfer tickets; the lady the fingers of her glove. Every one is busily engaged in this distribution of saliva, so that the end of each day finds this secretion freely distributed on the doors, window sills, furniture and playthings in the home; the straps of trolley cars; the rails and counters and desks of shops and public buildings; and, indeed, upon everything that the hands of man touch. Besides the moistening of the fingers with saliva and the use of the common drinking cup, the mouth is put to numberless improper uses which may result in the spread of infection. It is used to hold pins, string, pencils, paper, and money. The lips are used to moisten the pencil, to point the thread for the needle, to wet postage stamps and envelopes. Children 'swap' apples, cake and lollipops, while men exchange their pipes. Sometimes the mother is seen 'cleansing' the face of her child with her saliva-moistened handkerchief, and perhaps the visitor is shortly afterward invited to kiss the little one" (Chapin).

These habits are responsible for an immense number of infections, and yet it is extremely difficult to break ourselves of them. As a matter of fact, the diseases which are spread through the feces (typhoid, dysentery, and the summer diarrhea of infants) have decreased rapidly in recent years owing to public health measures.

Diseases spread through discharges from the mouth are much more difficult to control, and with some of them, as pneumonia, influenza, and measles, public health methods have as yet made practically no advance.

Fig. 36.—Eggs of the house-fly on the surface of a manure pile. The eggs are laid in manure or garbage, and require about ten days to grow into flies. Natural size. (From Newstead.)

A general viewpoint, of fundamental importance, which has been gained from our study of disease germs is this: we must not think of them as scattered broadcast over the earth. They are not. They are limited to *infected persons* and *to things which have been recently contaminated* with their excretions and secretions. It is the *infected person* that is the center for spreading

organisms, and the way he does it is *by actual contact* with another person or *through articles or insects soiled with his excretions. Disease germs remain closely associated with infected persons.*

Transmission of Disease by Insects.—Diseases are transmitted by insects in two ways. First, *mechanically,* as when a fly walks over material containing typhoid or dysentery bacilli, and then drops into milk.

Fig. 37.—The house-fly, under surface. Note the hairs on the legs and body. (Photograph by N. A. Cobb. Copyright by National Geographic Society of Washington, D. C.)

Second, *biologically,* when the pathogenic organism is actually taken into the insect's body and undergoes there a stage in its development.

Flies are the most common example of mechanical carriers. They may transport any kind of bacteria. These insects have a keen sense of smell and are attracted not only to food but to filth of all kinds, particularly feces. They have tiny hairs on the legs and body (Fig. 37), which wipe up the material over

which they travel. They also eat the filth over which they pass, and excrete it from the intestine in the form of flyspecks.

The reduction of flies is an important sanitary measure. Pits in which manure is deposited should be screened. Garbage should be kept tightly covered and should be collected frequently. No accumulations of filth of any kind should be permitted. Toilets, kitchens, and dining rooms should be thoroughly screened. Food exposed for sale should be protected by netting or glass during the fly season. As to the actual killing of flies, it is particularly important to destroy the *first ones of the season.*

The biological transmission of disease by insects is an entirely different process from mechanical carrying, and much more complex. It will be discussed under Insect-borne Diseases. The transmission of malaria and of yellow fever by certain species of mosquitoes is an outstanding example of biological transmission. The malaria organisms are taken into the stomach of the mosquito and actually infect the insect, undergoing a slow and complicated series of changes in the insect host. Eventually, after some days, the parasites invade the salivary glands of the insects and are thus ready to infect a new victim when the mosquito bites again. The process in yellow fever is more obscure and it is not known whether infection of the mosquito occurs or not, but the process resembles that of malaria in that *a definite time is necessary after taking in the virus before the insect's bite becomes infective.*

Human Carriers of Disease.—A person who has recovered from an infectious disease may *continue to give off the germs causing the disease for months,* or even

years, afterward. It is also true that persons who have been in *close contact* with those suffering from an infectious disease, as nurses and members of the family, may acquire the germs and yet not develop the disease. About 3 per cent of those who have had typhoid fever continue to pass typhoid bacilli in the feces, and persons who have been associated with diphtheria cases often have diphtheria bacilli in their own throats, and still remain well.

Persons who, although showing no signs whatever of disease, harbor and disseminate pathogenic organisms, are called "carriers." As described above, they may be classified as: (1) *convalescent* or *temporary* carriers, who rid themselves of the organisms in a few weeks after clinical recovery; (2) *chronic* carriers, who continue to shed the organisms for an indefinite period after recovery; and (3) *contact* or so-called "*healthy*" carriers.

Carriers have often proved to be the cause of outbreaks of different infections and, in fact, stand next in importance as a means of spreading disease to actual contact with a patient. They may be even *more dangerous than the patient* because they come in contact with more people and *no one suspects them.*

Contact with an unrecognized carrier explains the origin of many apparently mysterious cases of infectious diseases in which the patient is not known to have come in contact with another case of the infection. Only a very few carriers in any community are ever discovered, usually only those who have infected other persons; the vast majority are never suspected. Not only typhoid and diphtheria, but dysentery, pneumonia, cerebrospinal meningitis, infantile paralysis, and many other diseases are spread by carriers.

The only way to tell whether a person is a carrier is to examine him for the particular germ suspected; for example, to take material from the throat of a possible diphtheria carrier, and from the feces for typhoid or dysentery and have it examined in the bacteriological laboratory. The importance of carriers in spreading infection is being realized more and more. We shall discuss them more fully in connection with the diseases studied in the following chapters.[1]

Disinfection in Infectious Diseases.—Two kinds of disinfection are necessary in infectious diseases: that carried on *during* the course of the disease, and that which takes place *after* it has ended. They are called *continuous* and *terminal disinfection*, and the first is the more important.

Continuous disinfection means the immediate disposal of contaminated articles before the germs have a chance to be distributed; for instance, the burning of gauze handkerchiefs soiled with secretions from the mouth and nose, boiling dishes, soaking the bed and body linen in disinfectant solution, disinfecting the stools in infections of the intestine. The place where disinfection does the greatest amount of good is at the bedside, and as soon as possible after the excretions have been passed. This disinfection is the duty of the nurse, and it is just this painstaking, individual work that is of the greatest importance in stopping the spread of infections. Every nurse who carries it out conscientiously, intelligently, and thoroughly, either in the hospital or in the private home, may feel that she is protecting the com-

[1] For a more extended discussion of the carrier problem, see Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

munity and making an important contribution to public health.

By *terminal disinfection* is understood washing the woodwork, furniture, and all exposed surfaces with hot soapy water, wiping with a disinfectant solution, if possible putting on fresh paper and paint, airing the room for several days, and disinfecting the mattress and blankets, *after the termination of an infectious disease.* The more carefully the patient has been taken care of during the disease, the less necessity is there for terminal disinfection.

"It is quite as important to know what to disinfect, as how to disinfect and when to disinfect." The only way to know what to disinfect is to know, for each infection, how the organisms causing it are cast off, how long they remain alive outside the body, and how they enter the body to produce the disease. We shall take up these points for each organism considered in the following chapters.

In addition to terminal disinfection of the patient's surroundings, it is of course important to see that the patient is discharged in a clean condition and free from disease germs.

If strict precautions against the transfer of germs are taken, different contagious diseases can be cared for in the same ward, and no patient will catch the disease of another, that is, there will be no "cross infections." This is a test of the intelligence and carefulness of the nursing. In many infectious-disease hospitals two or three different diseases are treated in the same ward. The beds are separated by low partitions, merely as a reminder and to prevent droplet infection, and there are arrangements for washing and dis-

infecting the hands in each compartment, as well as sterile gowns and gloves to be used while in the cubicle and removed before proceeding to the next one.

Practical Applications to Ward Nursing.—The application to nursing of what we have discussed concerning the transmission of infection is simple in theory. In practice, it requires intelligence, knowledge, conscientiousness, constant attention and watchfulness, the refinement of little personal practices which are liable to be the means of transmitting bacteria, and very often the cultivation of an entirely new set of habits. The last two conditions involve special difficulties. The practical rules for clean nursing are so obvious that they sound commonplace, and yet, in any hospital it is almost impossible to have them carried out without variations or omissions.

The chief ways in which bacteria are carried around a ward have been summed up as fingers, food, flies, and fomites, *i. e.*, things which the patient uses or comes into intimate contact with such as bed linens, handkerchiefs or eating utensils. The most important of these is fingers. The nurse must train herself so that it is second nature for her to wash her hands thoroughly after handling articles which may be infected, and always before preparing the patient's food or going to her own meals, and never to touch any contaminated thing unnecessarily. If it is necessary to bring the hands into contact with infected material, rubber gloves should be worn.

Bedpans, sputum cups, and soiled dressings should be kept covered and disposed of as soon as possible. All articles contaminated by patients' excretions should, of course, be disinfected.

In mental hospitals, patients who help serve the food should be made to wash their hands before going into the dining room, and no patient who is not neat should be allowed to assist.

As to the prevention of infection of the nurse herself, it is a good rule to remember while on the ward never to put the fingers near the face, and to wash the hands thoroughly on leaving the ward.

When bacteria go directly from person to person they are more likely to be virulent than if they have existed for some time in the outside world. Typhoid bacilli passing immediately from the patient's feces through soiled hands into another person's mouth would be more likely to cause typhoid fever than the same organisms after they had grown for some months in the laboratory.

The number of infections arising in a ward where there are chronic patients is, to a large extent, a measure of the cleanliness of the conditions in the institution and of the carefulness of the nursing. A number of cases of sore throat, dysentery, or pneumonia occurring one after another in a ward means that the germs are being passed around in some way that could be prevented by suitable measures. In the case of dysentery, it may be that there are carriers of the germs who are helping to prepare or serve the food, or that the feces of dysentery patients have not been protected from flies and the latter are contaminating the food. In the case of sore throat, patients may be using towels or drinking cups in common, or the dishes which they use may not have been thoroughly washed. It requires constant watchfulness on the part of the nurse to guard against the transfer of bacteria from patient to patient in a ward.

CHAPTER XI

FOOD SANITATION

Types of diseases spread by food—How to guard against food infection and food poisoning—Milk: public-health supervision of supplies; diseases transmitted by milk.

Bacteriology[1] has a particularly close relationship to the preparation and handling of food because many pathogenic organisms enter through the mouth by means of contaminated food and drink, and also because, as most foods serve bacteria very well as culture media, they are frequently the agents by which infection is conveyed.

Types of Disease Spread by Food.—There are three ways in which bacteria in food may cause disease:

1. Bacteria known to cause infectious disease may get into the food by one of the methods indicated in this chapter, and grow there. Typhoid and paratyphoid bacilli and closely related bacteria are particularly frequent as causes of *food infection.* An organism closely related to paratyphoid bacilli and often the cause of serious food infections is *Salmonella enteritidis,* more commonly called *B. enteritidis.*

2. True *food poisoning* by bacteria is due to the growth in the food of an organism called *Clostridium*[2]

[1] The public-health aspects of food sanitation are discussed in Chapter XI of Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

[2] *Clostridium* is a special term for gram-positive spore-forming bacilli which can grow only where there is no air, as inside a sealed tin can or jar, in the center of a sausage, or, as in the case of C. tetani and C. welchii, in deep foci of dead tissue.

botulinum or B. botulinus which secretes an exotoxin into the food. This germ will be discussed later.

The disease caused by C. botulinum is not infectious since C. botulinum cannot invade the body. It causes disease only when the toxin which it forms in certain foods is swallowed.

3. The condition which used to be called "ptomaine poisoning" is now known to be, in the vast majority of cases, a real infection by disease-producing bacteria, as mentioned above, or poisoning due to B. botulinus which has grown in the food and given off a toxin, much as diphtheria bacilli grow in the throat and produce a toxin which is absorbed by the blood. Certain putrefactive, *saprophytic* bacteria, however, may grow in food and decompose it, giving rise to *putrefactive products.* These may cause gastro-intestinal irritation which might be classified as "ptomaine poisoning."

How to Guard against Food Infection and Food Poisoning.—*Thorough cooking* of food is a great safeguard against any harmful bacteria that may be present, but cooking to the point of sterilization is difficult in the case of large masses of food, as the *heat penetrates very slowly.* The outside of a roast or the top of a pudding may be browned, and yet the center may never be more than lukewarm. Steaming or boiling is more effective in sterilizing food than baking or frying. The thrifty housewife heats, and thus sterilizes, left-over food which she is afraid will not "keep" until it can be eaten.

Food poisoning by clostridium botulinum is usually fatal. It may very easily be guarded against, however, by heating all canned foods *to boiling* for a few minutes. This destroys the toxin formed by the germ. The modern improvements in the methods of canning

foods have practically eliminated the danger of food poisoning.

The cleanly preparation and serving of food is of great importance, both from the standpoint of general decency and also as a protection from disease. The first essential is clean hands, for bacteria, either harmful or harmless, are easily transferred from them to food.

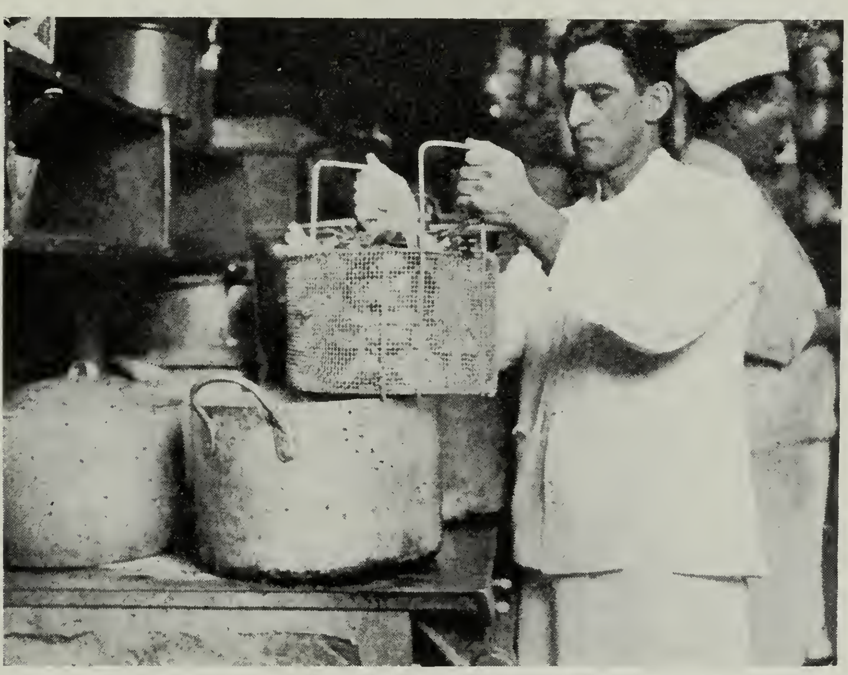


Fig. 38.—Scalding after dish washing—the safe way. (Photo by Lewis Hine. Courtesy of Cleanliness Institute.)

A few bacteria thus planted on food or in milk may increase enormously under favorable conditions. This will be further considered when we discuss typhoid and dysentery. The hands should always be washed thoroughly before preparing or serving a meal. The problem of clean hands is a pressing and difficult one in institutions like state hospitals where the patients

help in kitchens and dining rooms. Bacteria may also be distributed over food by rats, mice, roaches, and flies.

The protection of clean food from contamination by handling, flies, and other sources of contamination, is an excellent bacteriological precaution. The wrapping of bread at the bakery, and the serving of milk in bottles at restaurants are examples of this.

Many cities require that all applicants for places as *food handlers* in hotels, restaurants and institutions be examined for general cleanliness, typhoid carrying, tuberculosis, and syphilis, and that only those who pass the test satisfactorily be employed.

The *method of dishwashing* (Fig. 38) also has bacteriological importance. Washing dishes in a pint of lukewarm water with a dirty mop merely distributes bacteria over them. An abundance of *scalding water* should be used with *strong* soap. The proper washing of spoons, forks, and dishes that touch the mouth is especially essential. Clean dishwashing is of much importance wherever many people are fed—as in hospitals, institutions, or restaurants—for a poorly washed spoon or fork may be the means of carrying disease germs, like those of pneumonia or influenza, from one person's mouth to another's. Machine dishwashing is far cleaner than hand methods. In infections transmitted by saliva and sputum, the dishes and eating utensils of the patient should be *boiled*.

Milk.—Bacteria of most kinds grow well in milk, which contains more organisms than any other kind of "fresh" food. Mere numbers of bacteria, however, are not alarming; it is the kind that is important, and fortunately those in milk are usually harmless.

Milk as it is drawn from a healthy cow contains a few germs, but it acquires many more from the cow's body, the dust and dirt in the barn, the hands of the milker, etc. Some of this contamination is unavoidable, but it can be greatly reduced by care in the cleanliness of the cows, milkers, barns, cans, etc., such as is now observed in all good dairies. When it has just been drawn, very clean milk contains about 100 bacteria to each cubic centimeter. By the time milk reaches the city customer, from twenty-four to forty-eight hours later, the number of bacteria ranges from about 3000 per cubic centimeter in the very best milk to millions in a cubic centimeter of bad milk. Good, average grade milk contains about 50,000 bacteria in a cubic centimeter. These bacteria are usually harmless in themselves, but the presence of large numbers of them in milk shows that it has either been produced and handled under uncleanly conditions, or is stale, and has not been kept cool. It may also have come from cows with abscesses or inflammation of the udder.

Unless one knows, personally, exactly the conditions under which it is produced and handled, milk, especially for infant feeding, should be pasteurized in the household. A homemade pasteurizer may be arranged with a double-boiler and a thermometer; or, for infant feeding, a large covered kettle in which to set the nursing bottles will suffice, with some device to raise them off the bottom.

Public Health Supervision of Milk Supplies.—Good milk is so important that boards of health in all large cities and most smaller ones, regulate the conditions under which it shall be produced and sold. *Supervision of the milk supply* is a part of the work of the health

department. The farms on which it is produced are inspected, and sanitary conditions are enforced in the buildings, among the employees, in the care of the cows, and the handling of the milk. Milk from sick animals cannot be used, nor can the milk be marketed if there is a case of infectious disease among the family or employees on the farm. Milk must be kept in the refrigerator in the store and sold only by the bottle. No milk is allowed to be sold which contains more than a certain number of bacteria in each cubic centimeter.

In many communities *milk is graded or classified* according to the conditions under which it has been produced and the number of bacteria which it contains. "Grade A" is produced under exceptionally clean conditions, and is suitable for infant feeding. It may either be pasteurized or sold raw.

In the case of *certified* raw milk, special licenses have to be obtained and rigid medical and veterinary requirements complied with, all of which tend to safeguard the consumer. A certificate is issued to farms which meet the requirements and the milk is said to be "certified." "Grade B" is produced under ordinarily good conditions, and may safely be used for drinking by adults. It may or may not be pasteurized. "Grade C" is produced under poor conditions, contains large numbers of bacteria, and should be used only for cooking. In many communities such milk is not allowed to be sold.

In the household, milk should be kept *covered* and *cold.* The mouth of the bottle should be wiped with a clean cloth before the milk is poured out, unless the cap fits down over the top. Milk bottles should never be taken into a sick room.

Diseases Transmitted by Milk.—The diseases most frequently transmitted by milk are *typhoid fever*, *bovine tuberculosis*, *scarlet fever*, *septic sore throat*, *diphtheria*, and *undulant fever*.

The germs causing bovine tuberculosis gain entrance to the milk from infected cows; so also, probably, do the germs causing undulant fever. The organisms

Fig. 39.—Unclean bottling of unpasteurized milk. (Photo by Lewis Hine. Courtesy of Cleanliness Institute.)

causing septic sore throat and scarlet fever may get into the milk directly from some infected person who handles the milk, or indirectly by means of an infection in the cow's udder, which in turn came from an infected milker. The bacilli of typhoid fever and diphtheria gain entrance only from infected human beings, since cattle are not normally infected by these organisms.

All of these bacteria except the tubercle bacillus, grow in milk very well indeed, and may, if the milk is left in a

warm place, soon make a milk supply exceedingly dangerous.

The pasteurized and carefully guarded milk supplies of large cities are less often the means of spreading infection than is the milk consumed in rural districts and towns, which is often produced under unsanitary conditions, handled carelessly, and is almost never pasteurized. (Fig. 39.)

SECTION II

Special Bacteriology

CHAPTER XII

THE MICROCOCCI

Classification—*Staphylococcus albus*—*Staphylococcus aureus*—*The streptococci:* types; infections with beta type hemolytic streptococci; with the alpha type—Bronchopneumonia.

In a foregoing chapter we have pointed out that bacteria are divided, according to their shape, into three main groups: the cocci, (spheres); the bacilli (rods); and the spirilla (curved or spiral). We shall now discuss the first of these groups.

Classification.—Attention has already been drawn to the fact that cocci arrange themselves in different ways as they multiply. Those forming chains are called *streptococci*, those arranging themselves in irregular clusters are called *staphylococci*, while those which form pairs are called *diplococci*. The cocci are classified still further, according to the manner in which they grow in certain media and the changes they induce in certain substances. The micrococci which we shall study in this book may be classified for convenience according to their *staining reaction* as follows:

Gram-positive:

Staphylococcus albus
Staphylococcus aureus
Streptococcus hemolyticus (correctly called beta

type hemolytic streptococci)
Streptococcus viridans (correctly called alpha type hemolytic streptococci)
Diplococcus pneumoniae (often called pneumococcus)

Gram-negative: (All of these are diplococci)
Neisseria gonorrheae (often called gonococcus)
Neisseria intracellularis (often called meningococcus)

It must be pointed out that there are dozens of other types of cocci, some of them causing diseases of animals, most of them living harmlessly in the soil, in water, or upon the mucous membranes or skin of man and animals.

The staphylococci and streptococci were among the first pathogenic bacteria to be discovered. Staphylococci were first cultivated from pus in the laboratory by Pasteur in 1880, and streptococci, by Fehleisen, from erysipelas in 1883. (See Plate II, Figs. 1 and 2.)

The **Staphylococcus albus** is a very common and widespread germ. The syllables "staphylo" come from a Greek word meaning cluster, and the name is given because the cocci grow in groups like a bunch of grapes. It is called "albus" (white) because, when growing on culture media, it forms a chalky white coloring matter. It is widely distributed in the outside world and on the bodies of human beings and animals. It is always present on the skin as a harmless resident, but if the skin is injured through a cut, a scratch, or in other ways, the cocci get into the underlying tissues and may cause an infection.

The Staphylococcus albus grows easily and quickly in the laboratory. It is quite resistant to drying, and

can, therefore, remain alive for a considerable time (several months under favorable conditions) outside the body. It is a vigorous organism, not easily discouraged by unfavorable conditions. Boiling for three minutes, and ordinary disinfectants will kill staphylococci.

A boil is the commonest form of infection in which the Staphylococcus albus is found. Infection of stitches following operation is most frequently caused by the Staphylococcus albus. These infections are commonly called "stitch abscesses." As a rule it does not produce a dangerous inflammation, but in many cases it is very hard to get rid of. In many instances, however, it has been found in fatal septicemias.

Staphylococcus aureus is, in practically every respect, like Staphylococcus albus. It differs in producing a golden pigment (hence the name aureus) and in being a much more dangerous germ. It causes large boils, carbuncles, sometimes fatal septicemia, and abscesses in the internal organs called *multiple abscesses*. Infection of the bones, called *osteomyelitis*, may also be caused by *Staphylococcus aureus* as well as by *Staphylococcus albus* and some other organisms.

Both types of staphylococci always cause much pus formation. They produce a substance (leucocidin) which kills white corpuscles. It is easy to see that in handling staphylococcus infections, the greatest care should be exercised not to let the pus come into contact with anything which will distribute it. The germs are easily killed by boiling, since they do not form spores.

Staphylococcus infections, such as boils and infected wounds, are often very favorably influenced by vaccine treatment. The treatment has been most successful

in chronic infections, such as infected wounds, ulcers, chronic cystitis, and in localized infections, such as "crops" of boils. It is not used to any extent in acute infections.

The Streptococci form a large group or family of organisms, for there are family groups among bacteria, as among the higher plants and animals. The members of a group of bacteria may differ as widely from one another as races of the human species, and this is the case with the streptococci. Some are found in water and milk and are entirely harmless; others live in the human body and give rise to disease. We shall discuss here only the latter.

Streptococci are so called because they grow in chains, "strepto" coming from a Greek word meaning chain. They grow readily in the laboratory on blood or serum media, although they are less hardy than the staphylococci. They are easily killed by heat and antiseptics, but they may remain alive and virulent for some time when dried; for example, in sputum for several weeks.

Types of Streptococci.—We have indicated, at the beginning of the chapter, two types of streptococci. The names of these types are taken from their *action on red corpuscles.* They are distinguished as follows: If a tube of melted agar containing a little blood is inoculated with a few beta type hemolytic streptococci and then poured into sterile plates and incubated for twenty-four hours, the colonies will appear as tiny white specks each surrounded by a zone which is *perfectly clear and colorless* (see Fig. 40). These cocci have the power of causing the dissolution of the red corpuscles. The process is called *hemolysis* (from two Greek words, hemo = *blood,* and lys = *to dissolve*).

This type of hemolysis by streptococci is called the *beta type* (Greek letter β), and the streptococci are said to be hemolytic streptococci of the beta type. They are also spoken of as *Streptococcus hemolyticus.*

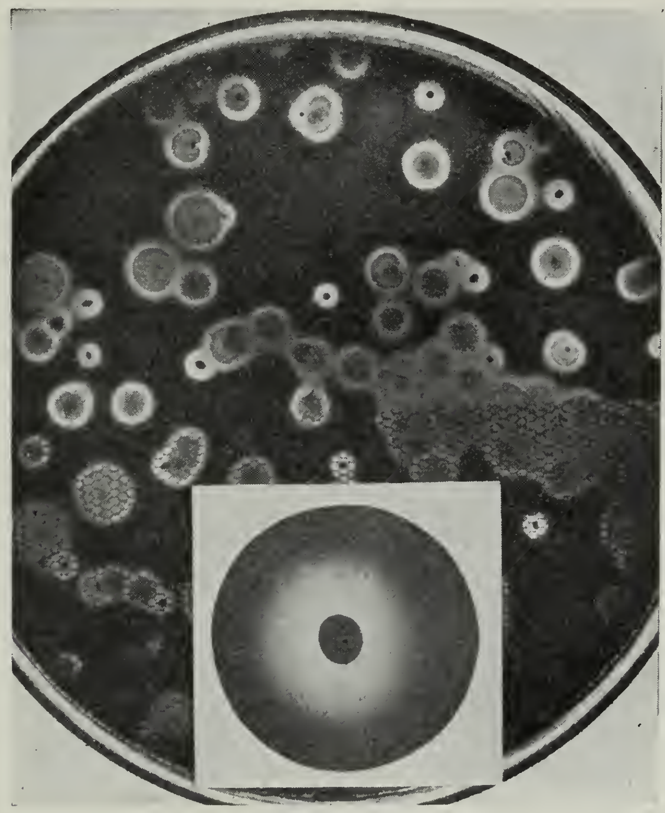


Fig. 40.—Natural size photograph of blood agar plate showing colonies of *beta type hemolytic streptococci.* Each colony is surrounded by a perfectly clear zone in which all the blood corpuscles have been completely destroyed. The insert shows one of the colonies much enlarged. Compare with Figure 112, which also shows hemolysis. (Courtesy of Dr. J. Howard Brown, Johns Hopkins University.)

Under the same conditions, some streptococci produce not only the clear zone but also a greenish zone close around the colony (see Fig. 41). Sometimes the green, central zone is so wide as to obscure completely the clear zone. Streptococci producing this greenish zone

are said to be hemolytic streptococci of the *alpha* (Greek letter A or α) *type.* They are also very widely spoken of as the viridans (green) type, or *Streptococcus viridans.*

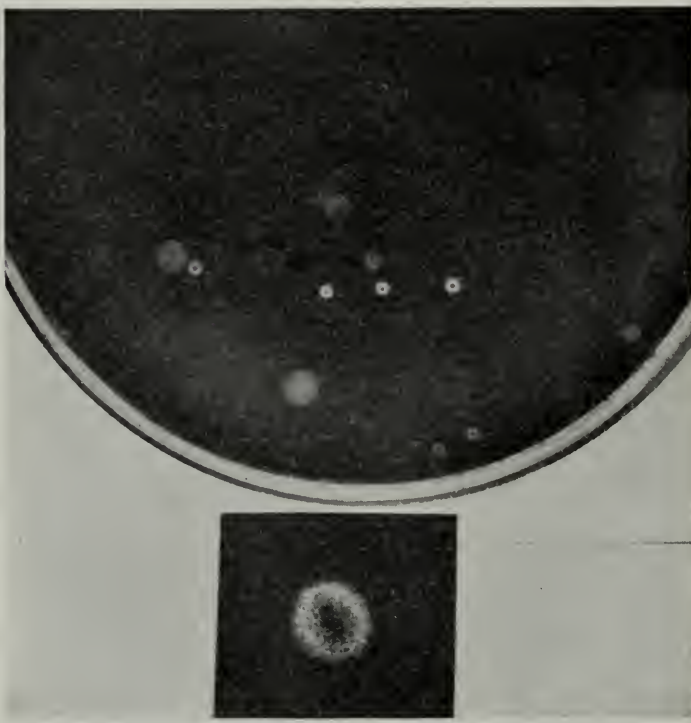


Fig. 41.—Natural size photograph of blood agar plate showing colonies of *alpha type hemolytic streptococci.* (Streptococcus viridans.) Each colony is surrounded by a small clear zone. In the center, close around the colony is a zone of greenish corpuscles. Sometimes this greenish zone is so wide as to mask the clear part. Often it is so narrow as to be visible only with the microscope as shown in the small insert. The colony may then be mistaken for a true beta type streptococcus colony. (Courtesy of Dr. J. Howard Brown, Johns Hopkins University.)

Diseases Caused by Streptococci.—The streptococci produce many diseases, most of which take the form of acute or chronic inflammations. Streptococcus infections are usually characterized by having little or no pus. **The acute streptococcus inflammations** are caused

almost exclusively by those of the beta type, and the chronic infections by the alpha type.

Infections with Beta Type Hemolytic Streptococci.—1. *Infection of the skin and underlying tissues* is one of the most frequent and dangerous conditions caused by beta type streptococci. They give rise to a very severe, rapidly spreading infection with much swelling, attended by marked general symptoms. This condition requires immediate surgical attention. The streptococci may enter through a very tiny break in the skin, as, for instance, when a surgeon pricks his finger through a rubber glove when operating on a streptococcus case. *Erysipelas* is another form of acute skin infection due to beta type streptococci. A large number of normal persons carry virulent streptococci in their mouths and on their tonsils.

2. Streptococci of the beta type are the germs most dreaded in surgery and obstetrics for they cause most of the fatal *infections after operation* and most cases of *puerperal fever.* Other germs are also frequently involved in puerperal fever. The greatest danger in streptococcus infections is that the organisms may get into the blood and cause blood poisoning or *septicemia.* This happens most frequently in the rapidly spreading infections of the skin, and in surgical and obstetrical cases. The onset of septicemia is marked by chills, high fever, and a change for the worse in the patient's general condition.

In confinement cases the bacteria may be carried into the uterus from the skin or mucous membrane which has been insufficiently cleansed, or on dressings or instruments that are not sterile, or on the hands of the doctor or nurse, if they have not been carefully disinfected.

Such infections are, therefore, preventable in practically every case, but they are all too frequent. In well-managed maternity hospitals serious infections almost never occur after uncomplicated cases, but they do sometimes happen when labor has been complicated and operative interference has been necessary. Every woman should, if possible, go to a hospital for confinement, because not only are there better facilities for treating any emergencies that may arise, but it is easier to carry out aseptic technic there than in the home.[1]

3. Streptococci of the beta type are the cause of some cases of *bronchopneumonia.*

4. It is very probable that a special kind of streptococcus is the cause of *scarlet fever*, although many workers in Europe and some in American do not feel entirely convinced of this.

There are no other organisms which cause more varied and more serious damage to the human body than do the streptococci. Infection with these organisms was one of the chief causes of death from disease during the World War, the most frequent forms being the infection of wounds with the streptococcus and the streptococcus pneumonia which complicates influenza and measles.

Infections with Alpha Type of Hemolytic Streptococci.—1. Streptococci, usually of the alpha type, are the cause of *abscesses at the roots of the teeth.* These may give no symptoms and be found only by the *x*-ray picture; yet the organisms or their toxins may cause serious damage to various organs.

[1] For the historical, public-health, and social aspects of maternal welfare, see Chapter XVI of Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

2. Alpha type streptococci are probably the cause of *acute rheumatic fever*, a systemic infection with a variety

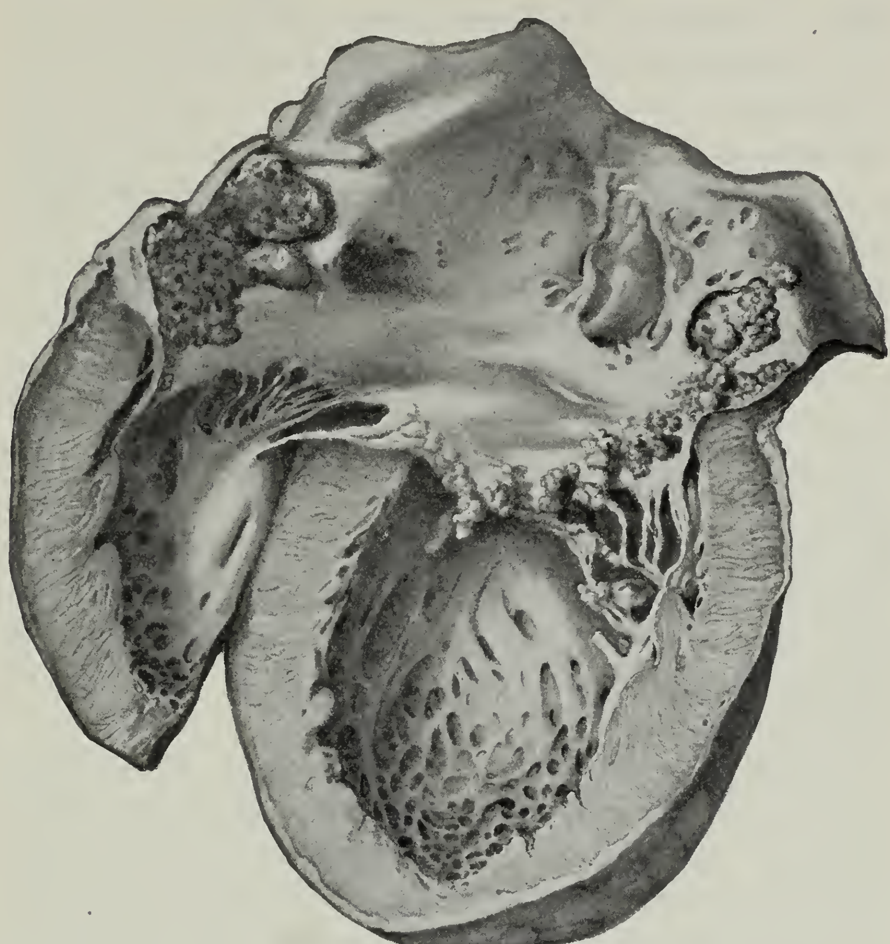


Fig. 42.—Endocarditis due to S. viridans. The heart has been cut open and we look into the left auricle and ventricle. On the leaflets of the mitral valve and the wall of the auricle are masses of inflammatory tissue called "vegetations." These heal with the formation of scar tissue, which causes deformities of the valves, preventing their closure or narrowing the opening. (From MacCallum "Text-book of Pathology.")

of manifestations. When it strikes the joints, it is called "inflammatory rheumatism"; when it affects the brain, it causes chorea (St. Vitus' dance). "Growing

pains" are another manifestation. It very frequently involves the heart, causing *endocarditis*, as described below. Just how the organisms are transmitted is not known exactly, but they may come from infected teeth and tonsils.

3. Streptococci, of the alpha type, as well as other types of bacteria, such as the gonococci, may cause an inflammation of the heart valves called *endocarditis* (Fig. 42). This is followed by shrinkage and thickening of the valves which causes them to leak. A rheumatic infection is the most frequent cause of those cases of valvular heart disease which begin in early life. In cases of endocarditis, the organisms are carried to the heart valves through the blood, very often from diseased tonsils or teeth. The care which is given children's throats nowadays and the removal of diseased tonsils and teeth in both children and adults is probably diminishing the number of streptococcic infections of the heart valves.

Bronchopneumonia (see description of *lobar pneumonia* below) is always a serious complication in other diseases. Often it is the condition which determines the fatal outcome, so that it is of the utmost importance to prevent its development if possible. Bronchopneumonia may be caused by one or more of a variety of organisms, among which are streptococci. The streptococci or other organisms causing bronchopneumonia may be in the patient's own mouth, or they may be brought to him from the outside on tableware, dishes, thermometers, or nurses' hands. The germs causing bronchopneumonia may be carried from bed to bed in a ward in this way. It is evident that patients who are especially liable to develop bronchopneumonia—that is,

those having chronic diseases or passing through acute diseases—must be protected from both the germs in their own mouths and those from outside. This involves special efforts to keep the mouth clean, the same nursing precautions in bronchopneumonia as in lobar pneumonia, and the greatest care to prevent carrying bacteria from one patient to another.

CHAPTER XIII

THE MICROCOCCI (Continued)

Scarlet fever: organism; toxin and antitoxin; transmission; nursing care; serum treatment; the Schultz-Charlton reaction; the Dick test; active immunity—*Diplococcus pneumoniae*—Lobar pneumonia: carriers; transmission; nursing; serum treatment: types of pneumococci—Pneumococcus vaccine.

Scarlet Fever Organism.—It appears not improbable that scarlet fever is caused by a special kind of hemolytic streptococcus, of the beta type, which can be differentiated by laboratory tests from the varieties causing tonsillitis, puerperal fever, erysipelas, and other streptococcic conditions. It has been known for a long time that hemolytic streptococci are almost constantly present in the throat in scarlet fever, that they are the cause of the complications of the disease, such as inflammation of the ear and of the glands of the neck, and that most of the fatal cases are due to them.

Toxin and Antitoxin.—In scarlet fever, beta type streptococci locate in the throat and produce a powerful *exotoxin,* which is distributed throughout the body by the circulating blood. In this respect scarlet fever resembles diphtheria. Not infrequently the cocci invade the blood stream. An *antitoxin* for scarlet fever has been prepared, which is as valuable in the cure of scarlet fever as diphtheria antitoxin is in diphtheria. There is also a test (the Dick test), described below, which shows who is susceptible to scarlet fever. There is also a method of giving permanent protection. Much

scientific work is being done on the disease at the present time, and if the new discoveries fulfil their promise, scarlet fever will soon be controlled as successfully as now is diphtheria.

Transmission.—The scarlet fever patient can spread the disease from the time of the very first symptoms, and remains infectious for a considerable time. Convalescents who are released from the isolation too soon may transmit the disease. A patient can spread the disease as long as there is any discharge from the nose, ears, glands, or any other part of the body, or as long as toxicogenic streptococci continue to live in his throat.

Scarlet fever is spread also by mild, unrecognized cases. Many cases are not noticed and it is these which keep the disease alive in a community and are the starting point of epidemics. The school doctor and nurse are always on the watch for these overlooked cases. Daily medical inspection of schools is the best method of finding them, and follow-up work by the nurse in investigating absent pupils will disclose mild cases at home which have no physician.

The disease may be spread by milk, in the same way as diphtheria. Pasteurization kills the organisms of scarlet fever.

Ninety per cent of the deaths from scarlet fever occur in children under ten years of age.

Nursing Care.—In nursing cases of scarlet fever extreme precautions must be taken to destroy by burning, or to disinfect thoroughly all articles contaminated with secretions from the nose and throat, and the nurse must take the same watchful care of her hands. Sputum cups may be burned; eating utensils may be boiled; thermometers should be

wiped clean and then immersed for at least ten minutes in a solution of disinfectant; bedding may be steam-sterilized or boiled. Infection of the middle ear during scarlet fever accounts for much of the *deafness* among children. Keeping the nose and mouth clean will help to prevent this complication.

Serum Treatment.—We have already pointed out that an antitoxin for scarlet fever has been developed. The method of making it is similar to the procedure followed in making diphtheria and tetanus antitoxin (see Chapter VIII). This serum has been used on patients with gratifying results.

The Schultz-Charlton Reaction.—If a little of this serum is injected locally *into* the skin (not under it) where the rash is visible, the rash soon disappears and the skin becomes white again (in white persons). This is called the *blanching reaction* of *Schultz-Charlton.*

The Dick Test.—The scarlet fever toxin itself can be used in very dilute form to *determine the persons who are susceptible to the disease. A very small amount* of the diluted *toxin* of the scarlet fever streptococcus is injected *into* the skin. If the person *has never had* scarlet fever, either clinically or sub-clinically as discussed in Chapter VI, and has not been artificially immunized (Chapter VIII), a red area, about the size of a quarter of a dollar, appears within twenty-four hours. This is due to the fact that the person tested does not have antitoxin in his system to offset the effect of the toxin which was injected. His reaction is said to be "*positive.*"

If the person is *recovering from* scarlet fever, or *has had the disease* in the past, or has been artificially immunized by receiving small doses of toxin subcuta-

neously as discussed in Chapter VIII, he is not susceptible, the reaction is *negative*, and no red spot appears. This is called the *Dick test* after the two Chicago physicians who discovered it in 1923 and it promises to have as great practical value in scarlet fever as the *Schick test* has in diphtheria (Fig. 66). The spot, if it appears, remains for about one to two days and then disappears quickly, leaving no scar. The test is perfectly harmless.

Immunity.—It is possible to produce an *active immunity to scarlet fever* by injections of small amounts of the streptococcus toxin into the system at intervals of a week. This promises to be of great value in protecting not only children but also physicians and nurses. Some hospitals are already *examining* their nurses by the *Dick test* and *immunizing* those who give a positive reaction.

An illustration of the value of testing and immunizing nurses is given by the experience of the Durand Hospital for contagious diseases in Chicago.[1] During the ten years and nine months preceding the introduction of the Dick test and immunization, 40 cases of scarlet fever occurred among 516 nurses, 7.7 per cent. During the seven years following routine testing and immunization, there were 3 cases among 473 nurses, 0.06 per cent. Two of these cases occurred in nurses whose immunization had not been completed before entering the service; the third nurse had escaped testing. Among those who were completely immunized before starting their course, there were no cases of scarlet fever. Thirty per cent of the nurses tested were susceptible.

[1] Johnson, Charlotte, R. N., American Journal of Nursing, Vol. xxxi, p. 318.

These procedures give for scarlet fever what we now have for diphtheria—a *test to determine susceptibility* to the disease, *a method of giving permanent protection*, and *a serum for cure of the actual disease.* It now appears probable that the control of scarlet fever will make great advances within the next few years, as these methods come into more general use.

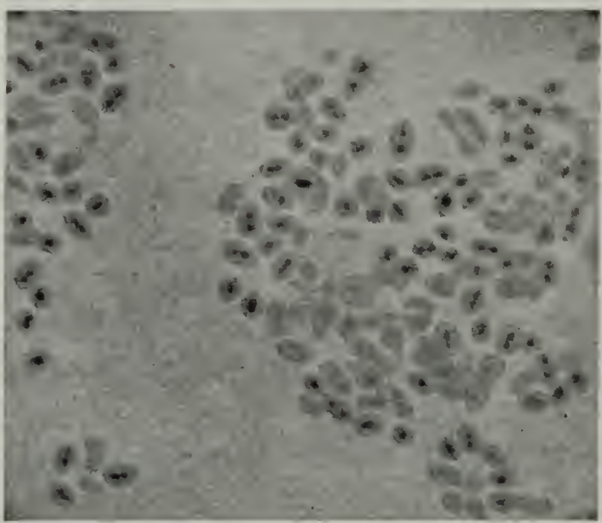


Fig. 43.—Pneumococci with capsules in a smear preparation from pericardial exudate stained by W. H. Smith's method; × 1500. (W. H. Smith; photo. by L. S. Brown.)

Diplococcus pneumoniae.—Pneumococci were demonstrated in saliva by Pasteur in 1880, but it was not until 1886 that they were proved by other medical workers to be the cause of lobar pneumonia.

The pneumococcus always grows in pairs. (See Plate II; Fig. 3.) It is called a diplococcus (*diplo* is from a Greek word for double). Each pneumococcus of the pair is slightly pointed. Each pair is enclosed in a mucus-like envelope called a *capsule,* which can be seen with the microscope when stained by a special process (Fig. 43). It also appears as a halo

around the bacteria when they are suspended in a little india ink and smeared on the slide.

A similar mucus-like envelope is formed by a great number of bacteria, including many types of hemolytic streptococci. It is frequently found associated with particularly virulent forms and is believed to serve the bacteria as a protective covering to help them withstand the antibodies and leukocytes.

The pneumococci produce the same sort of appearance in blood agar as do the alpha type streptococci. They can be distinguished from streptococci by the remarkable property of dissolving when a little bile is added to a broth culture of them.

The pneumococcus is a delicate organism, growing with some difficulty in the laboratory. It is easily killed by heat and disinfectants. In dried sputum, however, it can remain alive for a considerable time when protected from air, moisture and light. The sputum of a pneumonia patient contains pneumococci in great numbers.

The pneumococci form a family or group of organisms, just as do the streptococci. The members of the group differ from one another in various ways; some types produce a more severe pneumonia than others. Laboratory examination of a patient's sputum will reveal which variety of pneumococcus is causing the infection. It is important to know this because it gives some idea of how severe the disease is liable to be, and it may help in deciding the treatment, since the kind known as *Type I* frequently yields to serum treatment, while the others do not yield so readily.

Lobar pneumonia is an *acute infectious disease.* (Note for student: Distinguish carefully between

broncho- and lobar pneumonia.) *Lobar pneumonia* derives its name from the fact that one or more entire lobes of the lung become infected at the same time (Fig. 44). It is very seldom caused by any germ but the pneumococcus. *Bronchopneumonia* may be caused by any one of a number of organisms but particularly by streptococci. It localizes in *patches scattered* throughout the lungs.

Lobar pneumonia is one of the most frequent and fatal of all acute diseases. In 1929 pneumonia, including all forms, ranked third as a cause of death in the United States, causing 106,597 deaths, and being exceeded only by heart disease and cancer.

Carriers.—A person who has recovered from pneumonia may carry the pneumococcus in his saliva for weeks, or even as long as three months. If such a person coughs or sneezes without covering his mouth, in a car or theater or any crowded place, if he handles things with fingers moist with saliva, or if his dishes and tableware are not disinfected, he will be likely to distribute the germs to his defenseless neighbors, who, in turn, may develop the disease.

Those who have been closely associated with a pneumonia case, as a nurse and members of the family, may also have the pneumococcus in their throats, although they may never develop the disease. These persons are *carriers*, as described in Chapter X, and they may scatter the germs in the same way as a convalescent from pneumonia. Less is known about pneumococcus carriers than about typhoid and diphtheria carriers; in fact, we are only beginning to learn about them, but they are undoubtedly of great importance in transmitting the disease.

Transmission.—There are *three chief ways in which lobar pneumonia is spread:* (1) by the sputum and

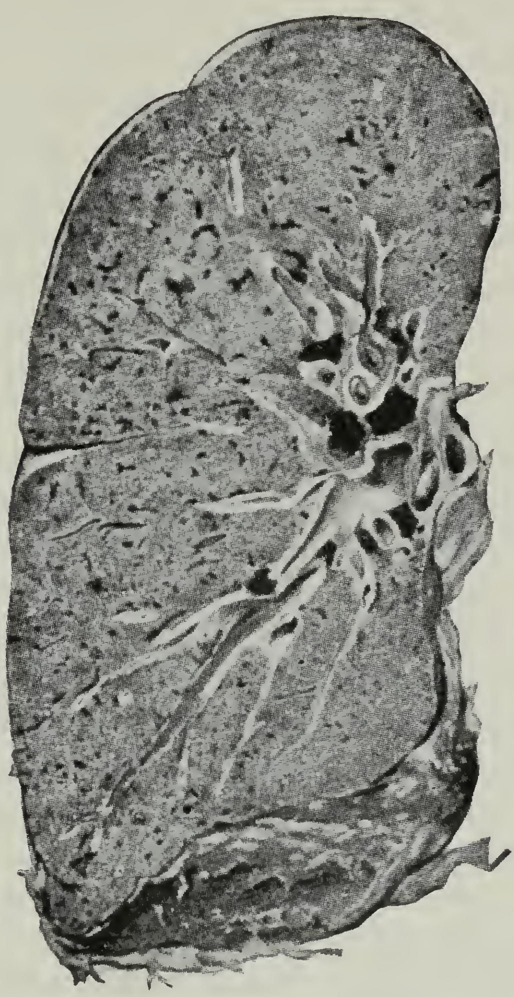


Fig. 44.—Lobar pneumonia; section of the lung. The entire lung is solid because the alveoli are filled with exudate. When the patient recovers, the whole mass of exudate is liquefied within a few days. While some of it is brought up as sputum, the greater part is absorbed through the lymphatics of the lung. In the lower part of the picture the inflamed pleura is seen with tags of fibrin adhering to it. (From MacCallum "Text-Book of Pathology.")

saliva of a pneumonia patient, (2) by convalescents who still have the germs in their saliva, and (3) by

healthy carriers. A fourth but less important means of transmitting the disease is infected dust. Pneumococci have been found in the dust from houses in which cases of pneumonia had occurred. When lobar pneumonia develops, it means that the patient has acquired the pneumococci either from a previous case or from a carrier.

The nursing of a case of pneumonia should be that of a communicable disease. Each case must be regarded as a possible starting point for other cases, and every opportunity for the infection of others must be avoided. The sputum should be received in paper cups and burned, together with the gauze or paper handkerchiefs used by the patient. The greatest precautions must be taken to disinfect everything soiled by sputum and saliva. The sterilization of dishes, tableware, and thermometers is especially important. The patient's mouth should be kept clean and an antiseptic mouth wash used frequently. If the patient is in a ward, the bed should be screened, so that he will not infect his neighbors when coughing. As few people as possible should come in contact with the patient, in order to prevent the making of carriers. The nurse must guard against becoming a carrier herself by disinfecting her hands in the same way as in other infectious diseases, and by avoiding droplet infection when the patient coughs.

In state hospitals and other institutions where there are chronic and infirm patients, there are probably always carriers, as cases of pneumonia keep cropping out among patients who have not been off the ward for months. More careful isolation and nursing of the actual pneumonia patients would reduce the number of cases of the disease in these institutions.

The Serum Treatment of Pneumonia. Types of Pneumococci.—There are different varieties, or *types*, as they are called, of pneumococci. Three distinct types (the so called "fixed" types) of pneumococci are recognized; these all look alike under the microscope and grow in the same way in the test-tube, but they can be distinguished by certain complicated laboratory tests, and they differ in the seriousness of the pneumonia which they produce. Types I and II each produce about one-third of all cases of pneumonia.

Type III is less frequent, but it causes a very grave form of the disease. These pneumococci have very heavy capsules. This, as has been pointed out, may be closely associated with their virulence.

Pneumococci not belonging to Types I, II or III are grouped together and are spoken of as group IV. Group IV pneumococci are often found in the mouths of normal persons and usually cause a milder form of the disease than do any of the other types, although they may also cause fatal infections at times. Each type produces its own particular variety of antibodies which are effective only against that particular type of pneumococcus.

The type of pneumococcus infecting a patient may be determined by *agglutination* tests similar in principle to the agglutination test used in the diagnosis of typhoid fever (see Chapters VII and XVI). A test performed in much the same way is called the *precipitin* test and gives the same information. The process of determining which type of pneumococcus is infecting a patient is commonly spoken of as "typing," and a patient's sputum is frequently sent to the laboratory to have the pneumococci "typed."

Many scientists have been working in recent years to prepare a curative serum for pneumonia. Up to the present time an efficient serum has been produced only against Type I. This is prepared by injecting a horse first with killed and then with living Type I pneumococci. The curative serum is given intravenously.

The serum is of value only in pneumonia caused by the Type I pneumococcus; it does not protect against the pneumonias caused by Types II, III, and IV. The *results* of the use of Type I serum have been most encouraging. With its use there has been a drop in the death-rate of Type I cases to about 8 per cent as contrasted with the usual death-rate of about 20 per cent in untreated cases. It must, however, like all sera, be given early in the disease, and injections must be repeated every eight or ten hours as long as seems advisable. The outcome of a case of pneumonia depends largely on whether the pneumococci get into the blood in large numbers. When this occurs, recovery is very rare. The early use of serum may not entirely check the process in the lung, but it probably does help in limiting it to the lung and preventing the pneumococci from invading the blood. *When a patient has developed pneumonia, a specimen of sputum should be taken at once and typed.* Treatment will thus be started at an earlier stage of the disease, and perhaps the serum may be given as a preventive measure to persons who are threatened with pneumonia. It is quite possible that effective sera against the other three types of pneumococci may soon be prepared, and also that the improvement of pneumococcus serum may pave the way for more efficient serum treatment in other diseases.

Pneumococcus Vaccine.—A vaccine made of killed pneumococci has been, and is still being tried for the prevention of pneumonia, but no definite statements as to its value can be made at present. The results are encouraging but not decisive. The protection afforded by it is certainly not as great or as prolonged as in the case of antityphoid vaccine; nevertheless, it might be of considerable value for persons who are especially liable to develop pneumonia, as elderly people or invalids.

CHAPTER XIV

THE GRAM-NEGATIVE COCCI (NEISSERIA)

The gonococcus—Gonorrhea: in the female; in the male—Gonococcus vaginitis—Gonococcus ophthalmia—*The meningococcus*—Meningococcus meningitis—Antimeningococcus serum.

The Gonococcus (Neisseria gonorrheæ).—This organism was discovered in 1879 by a German physician, Neisser, hence its name *Neisseria.* It has a characteristic appearance when seen with the microscope, the cocci being shaped like beans, and always occurring in pairs. It is, therefore, a *diplococcus.* It is Gram-negative. (See Plate I; Fig. 4.)

The gonococcus is a very delicate organism and is difficult to cultivate in the laboratory, requiring serum or ascitic or hydrocele fluid for its growth. It has little resistance to heat, light, drying, or disinfectants, and dies quickly outside the body. When kept moist and protected from light, it may live in gonorrheal pus on sheets or clothing for as long as eighteen to twenty-four hours. It is most easily killed by chemicals containing silver. These are used for its destruction in the form of silver nitrate, argyrol, or protargol.

The *diagnosis* is made in the acute stages of a gonococcus infection by finding the cocci with the microscope in stained specimens of the pus. They are characteristically enclosed within the leukocytes. (Fig. 45.) In the chronic stages gonococci are very scarce, and more complicated laboratory procedures may be required to make the diagnosis. The *complement*

fixation reaction is sometimes used in such cases. It is exactly like the Wassermann test (Figs. 27 and 28) except that, since an amboceptor against gonococci is being tested for in the patient's serum, the antigen must consist of gonococci instead of the alcoholic tissue extracts used in the test for syphilis.

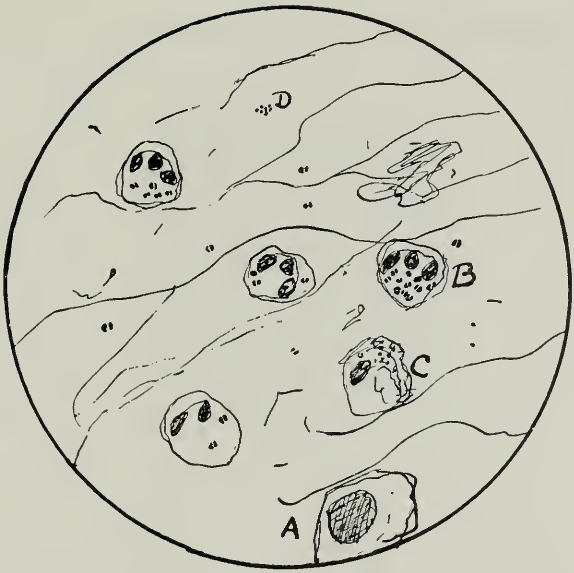


Fig. 45.—Stained smear of pus from a case of gonorrhea. A, tissue (epithelial) cell; B, leukocyte filled with gonococci; C, leukocyte partly destroyed; D, other bacteria (probably staphylococci), often seen in such smears.

Gonorrhea is an infection of the urethra and reproductive organs in both men and women, caused by the gonococcus. It begins as an acute inflammation which later becomes chronic. A great deal of pus is formed in the early stages, and may actually drip, unless absorbed by clothing or dressings. It is one of the most frequent of all the serious infectious diseases. Although accurate statistics are not available, recent reliable studies indicate that in this country about 474,000 cases of gonorrhea

are constantly under medical care. In addition, there are great numbers of cases who remain untreated. It is transmitted in the great majority of cases by sexual intercourse, although gonococcus infections of other parts of the body and infections of children are acquired in other ways, which will be described later.

Gonococcus infection is seldom fatal, but it is exceeding difficult to cure. It often starts up again after long treatment, when the patient believes he has been cured. Under such conditions a husband may infect his wife soon after marriage. It is never possible to say that a gonorrheal patient has really been cured.

In the female, the gonococcus causes an inflammation of the vagina, uterus, fallopian tubes, and ovaries. This condition is quite common and makes necessary many gynecological operations. In most gynecological clinics it is the custom to examine the uterine secretion of every patient for the gonococcus.

In the male, the gonococcus causes inflammation especially of the urethra. This may spread to adjacent portions of the genito-urinary system. The seminal vesicles, prostate and bladder may be affected. The urethra may become so scarred that urine cannot pass. This condition is commonly called *stricture* and requires surgical treatment.

Gonorrhea is one of the most frequent causes of childless marriages because it destroys parts of the genital organs. In the female the fallopian tubes frequently become closed by scar tissue which replaces tissues destroyed by the intense local inflammation set up by the gonococci. In the male a similar process results in the occlusion of the vas deferens. The

former condition prevents the ova of the female, and the latter prevents the sperm cells of the male from reaching the uterus, sterility being the result.

Gonococcus Vaginitis.—This is a fairly common disease in little girls. The infection of children in families in which there is an adult case of gonorrhea is more frequent than is ordinarily supposed. Infection comes about by sleeping in the same bed or by the common use of washcloths, towels, bath-tubs and

Fig. 46.—The end result of ophthalmia neonatorum due to the gonococcus. The person in attendance at birth failed to instill silver nitrate solution into this child's eyes. The mother had gonorrhea. (Courtesy Boston Nursery for Blind Babies.)

toilets. The disease may spread in epidemic form in hospital wards, schools, and children's homes. It is exceedingly difficult either to cure the condition in the individual child, or to prevent its transmission to other children. It is the custom in all well-managed hospitals to delay the admission of little girls to the general children's ward until vaginal smears have been taken and found negative for gonococci. If the disease has once broken out in an institution, only the most rigid precautions in the handling and treatment of the cases will prevent its spread. Gonococcus vaginitis

may also occur in little as well as older girls through criminal assault by an infected man.

Gonococcus Ophthalmia.—Inflammation of the eye, or ophthalmia, caused by the gonococcus is one of the most serious infections that can occur in that organ. The disease occurs both in adults and in newborn babies. A patient with gonorrhea may infect his eyes by means of his hands. Doctors, nurses and medical students sometimes contract gonorrheal ophthalmia through caring for patients.

If a woman who has gonorrhea gives birth to a child, the baby's eyes may become infected during the process of birth, and unless the condition is treated promptly and vigorously, the child's sight may be destroyed within a few days (Fig. 46). The disease in newborn babies is called *ophthalmia neonatorum* (newborn).

Not all inflammations of the eyes of newborn babies are due to the gonococcus, but those caused by other bacteria do not usually have serious results. Some are caused by carelessness in washing the eyes, and are due to the Staphylococcus aureus, or other organisms, but it is impossible to distinguish the various kinds without examining the pus from the eyes with the microscope.

The number of cases of blindness due to the gonococcus is diminishing in civilized countries (Fig. 47) because of the general practice of putting a drop of a silver preparation into each eye immediately after birth. If done properly, this is an almost sure prevention of gonococcus ophthalmia. In the Sloane Maternity Hospital in New York City there were 4660 births during a period of six years in which this method was carried out, without a single case of ophthalmia neo-

natorum. The disease is so easily prevented that its continued existence is criminal; yet only by eternal vigilance can protection from it be assured to every newborn child.

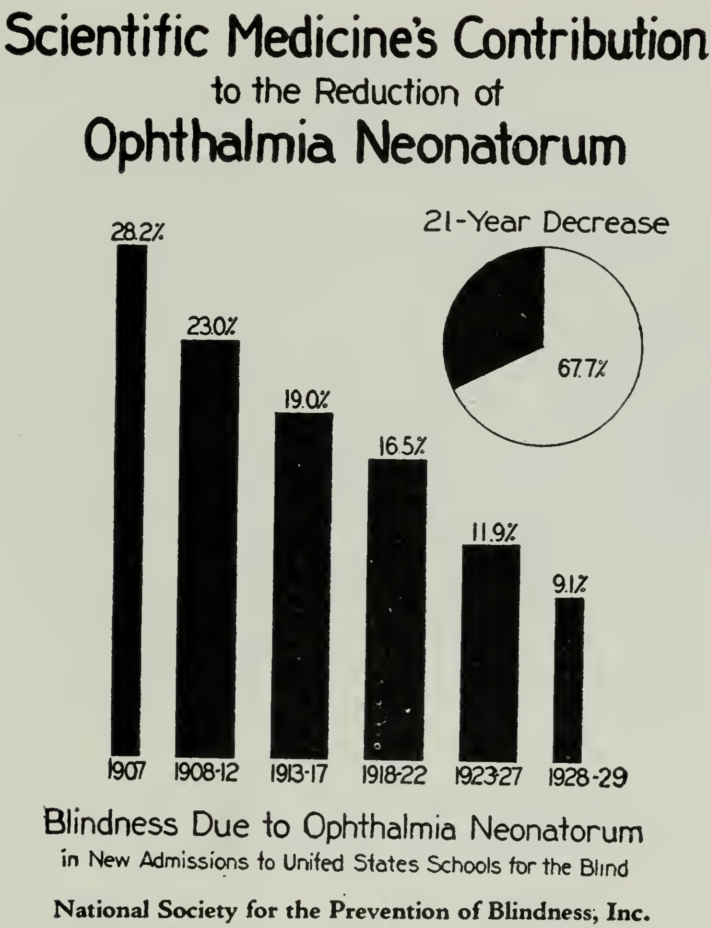


Fig. 47.

The man to whom humanity owes this decrease in ophthalmia neonatorum is *Karl Credé* (1819–92), professor of obstetrics at Leipsic, Germany. In 1884 he introduced the use of silver nitrate solution, thereby reducing the occurrence of ophthalmia neonatorum in the hospital from 10.8 to 0.1 per cent.

In most states the use of a silver preparation in the eyes at birth is required by law, and also the reporting to the health department within twenty-four hours of any inflammation of the eyes of a newborn baby. Outfits for

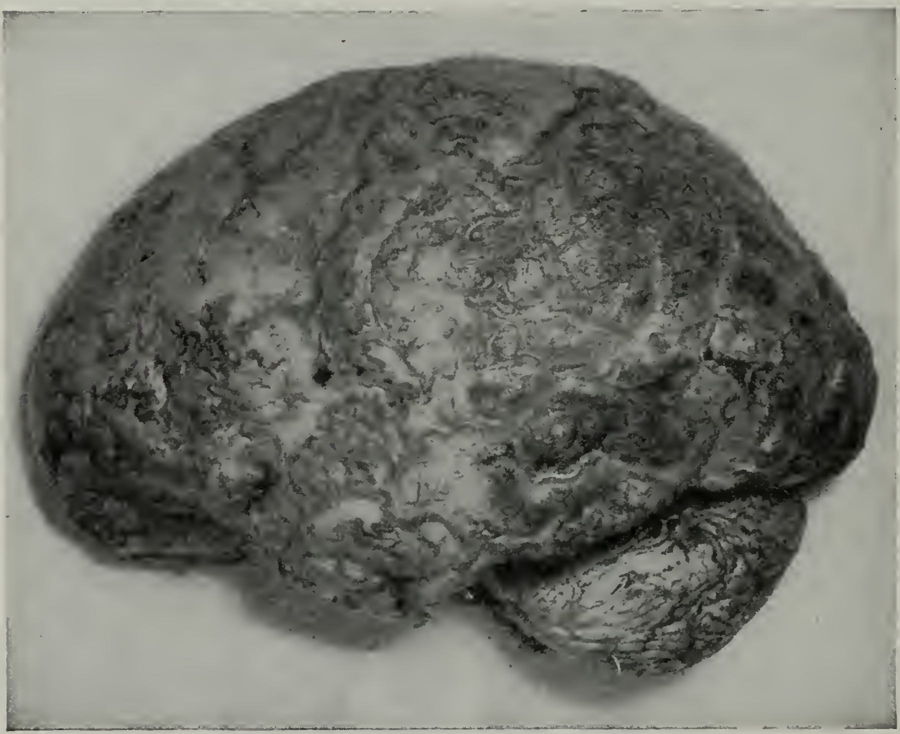


Fig. 48.—Meningococcus meningitis. The entire surface of the cerebrum is covered with a thick layer of purulent exudate which obscures the convolutions. The pus is held in the meshes of the pia mater. (From MacCallum "Text-book of Pathology.")

treating the eyes at birth are furnished free by most health departments.

The Meningococcus (*Neisseria intracellularis.*).—This organism exactly resembles the gonococcus in staining, morphology, cultural requirements, and fragility. As in the case of the pneumococcus, there are a number of types of the organism. The meningococcus ferments certain substances not fermented by the

gonococcus. It causes a very dangerous and frequently fatal inflammation of the coverings (meninges) of the brain and spinal cord (Fig. 48). The disease is called cerebrospinal meningitis (cerebrospinal fever).

Meningococcus meningitis occurs usually in small epidemics, and is therefore called *epidemic meningitis.* This form of meningitis should be differentiated from other types of meningitis which may be caused by streptococci, pneumococci, and other bacteria, but *never occur as epidemics.* Children are most often affected. The disease is spread chiefly by *carriers.* The connection between cases is usually difficult to trace, as is true of all infections spread by carriers. Persons directly associated with the patient contract the disease only infrequently, although they often become carriers.

The meningococcus enters the body through the nasopharynx (Fig. 49) *and probably reaches the meninges through the blood.* The disease is probably therefore, in its early stages, a *septicemia.* Meningococci are found quite constantly in the secretions of the nose and mouth during the first days of the disease.

It is customary to take material from the nasopharynx for bacteriological examination in order to discover carriers.

Antimeningococcus Serum.—*An efficient curative serum for epidemic meningitis has been prepared by the injection of horses with cultures of different varieties of meningococci.* In order to kill the organisms in the spinal fluid, *the serum is injected directly into the spinal canal of the patient by means of lumbar puncture,* after allowing some cerebrospinal fluid to run off. This serum, having been prepared by the injection of several

different types of meningococci into horses, is a *polyvalent* serum, just as a polyvalent vaccine is one prepared from several different types of the same species of bacteria (Chapter VIII). An average dose of serum

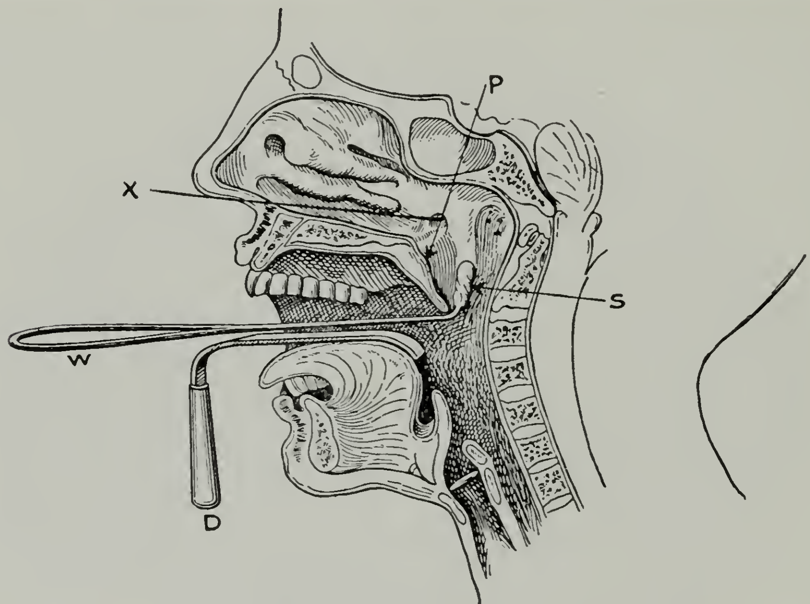


Fig. 49.—Illustrating the method of taking material for cultural examination from the nasopharynx by means of a special swab: W, wire holder of swab (S); P, soft palate; D, tongue depressor. Sometimes a swab is passed back through the nostril as shown at X.

for an adult is 30 cc. The treatment is repeated daily for three or four days, and longer if necessary. Serum is also given intravenously to kill the meningococci in the blood.

The *death-rate* from meningococcus meningitis before 1906, when the serum came into use, varied between 60 and 80 per cent. The effects of the treatment depend, as with every other curative serum, on the stage of the disease at which it is begun. The results obtained in large series of cases treated in various countries are given in the following table:

Treatment Begun	Death-rate
Before third day	7–18 per cent.
From fourth to seventh day	11–27 per cent.
After seventh day	24–50 per cent.

In any case in which there is a suspicion of meningitis, it is of extreme importance to make a lumbar puncture

Fig. 50.—Meningococci in the leukocytes in the cerebrospinal fluid in a case of epidemic meningitis. The cocci occur in pairs and look like gonococci (see Plate I; Fig. 4). The network between the cells is fibrin. (Jordan.)

immediately and examine the cerebrospinal fluid bacteriologically. The diagnosis is made usually from a Gram-stained smear of *the sediment* (see Fig. 50). Cultures may also be made, but the results of these are usually too slow in preparation to be of much diagnostic value.

CHAPTER XV

THE GRAM-NEGATIVE PATHOGENIC BACILLI GROUP I

Classification of pathogenic bacilli—(*A*) *The Gram-negative bacilli*—(1)—*The intestinal group*—*B. coli*—*B. typhosus* and typhoid fever—How typhoid is spread—Diagnosis: blood and stool cultures; Widal reaction; the agglutination test for suspected typhoid bacilli—*B. paratyphosus A and B:* paratyphoid fever.

Classification.—As in the case of the micrococci, there are both Gram-positive and Gram-negative bacilli. Some types of bacilli are motile; some are spore-bearers. In addition, there is a large group of bacilli which are so constituted that they can grow only when air is excluded.

The various bacilli which we shall discuss in this book may be tabulated as follows:

A. Gram-negative

(No Spore-bearers)

I
- B. coli (Escherichia coli). Cystitis. Constant inhabitant of intestines. Usually harmless.
- B. typhosus (Eberthella typhi). Typhoid fever.
- B. paratyphosus A (Salmonella paratyphi) } Paratyphoid fever.
- B. paratyphosus B (Salmonella schottmülleri) } Paratyphoid fever.
- B. dysenteriae (Eberthella dysenteriae). Bacillary dysentery.

II
- B. influenzae (Hemophilus influenzae). Probably not related to influenza. Sometimes causes general infections or meningitis.
- B. pertussis (Hemophilus pertussis). Whooping cough.
- B. bronchisepticus (Alkaligenes bronchisepticus). Disease resembling whooping cough.

III
- B. ducreyi (Hemophilus ducreyi). Soft chancre.

IV
- B. melitensis (Brucella melitensis). Undulant fever.

B. Gram-positive

I. *Aërobic or facultative*
- B. tuberculosis (Mycobacterium tuberculosis). Tuberculosis.
- B. anthracis (Bacillus anthracis). Anthrax ("malignant pustule").
- B. diphtheriae (Corynebacterium diphtheriae). Diphtheria.

II. *Strictly anaërobic.* The three listed here are spore-bearers.
- B. welchii (Clostridium welchii) gas gangrene.
- B. tetani (Clostridium tetani). Tetanus (lockjaw).
- B. botulinus (Clostridium botulinum). Botulism (food poisoning).

The letter B. is an abbreviation of the word *bacillus*. The correct bacteriological name of each organism is given in parenthesis following its common name. The disease most commonly caused by each organism is given after the correct name. In this book, for convenience, the commoner names are used.

The Gram-negative Bacilli.—As indicated above, the organisms to be considered under this heading may be divided into four groups; first those which are related to the intestine and its diseases, second, those related to the respiratory tract, third, a single bacillus causing a disease of the external genitalia and adjacent parts, and fourth, a bacillus causing a febrile disease. With the first group we shall also discuss briefly the organism which causes Asiatic cholera. This is a spirillum, but in many respects it is so much like the bacilli of this group that it may as well be considered at the same time.

The Intestinal Gram-negative Bacilli.—The organisms of this group have many characteristics in common. In addition to being Gram-negative bacilli which look alike under the microscope, they all grow well on ordinary laboratory media at temperatures ranging from 20 to 39 C. Since they do not form spores, all are easily killed by a few minutes boiling, by pasteurization, and by good disinfectants as ordinarily used.

All except B. dysenteriae are motile. They differ in their action on various carbohydrates. Some change various carbohydrates into acid and gas, some do not. These differences are shown clearly in Table I, and are the principal fermentation reactions used to identify the members of the group.

All of these organisms are discharged from the body in the feces, and sometimes in the urine, and they gain entrance to the body through the mouth. The diseases they cause are all, therefore, transmitted in the same way, *i. e.*, by anything polluted with fecal material or urine.

Table I.—Characteristics Commonly Used to Distinguish between Bacilli of the Gram-negative Intestinal Group

Organism.	Action on common carbohydrates (sugars).			Motility.
	Lactose (milk sugar).	Dextrose (glucose).	Saccharose (cane sugar).	
B. typhosus	No change	Acid only	No change	Active
B. paratyphosus	No change	Acid and gas	No change	Active
B. dysenteriae	No change	Acid only	No change	None
B. coli*	Acid and gas	Acid and gas	Acid and gas	Active

* Some strains of B. coli do not ferment saccharose.

Bacillus Coli (*Escherichia coli*).—This organism is one of the most widely distributed bacteria in nature, being found in the intestinal canal of all animals and of human beings. It is discharged with feces in enormous numbers. Ordinarily it does no harm and may be of value in aiding the physiology of the intestines. It probably also is useful in promoting rapid decomposition of fecal matter after it leaves the body.

B. coli may at times cause disease, if given a sufficient opportunity, such as a very dirty wound or an old, slowly healing ulcer, especially if the general health and nonspecific resistance of the patient is low. B. coli may cause more serious trouble by invading the bladder and pelvis of the kidney. Here it causes a chronic and often very stubborn inflammation. In the bladder this is called *cystitis;* in the pelvis of the kidney, *pyelitis.*

B. Typhosus and Typhoid Fever.—The typhoid bacillus (Fig. 11) was discovered by a German physician (Eberth) in 1880, in the spleens of typhoid patients who had come to autopsy. It had been known for some time before this, however, that typhoid fever was an infectious disease. Although the bacillus develops chiefly in the human body, it is also found in the outside world in water polluted by the excreta of typhoid cases, and it can grow very readily in milk. It is quite hardy outside the body and can survive for some time in water, sewage, oysters, etc. Observations have shown that it may live for seven days in water, twelve days in sewage, four months in butter, and thirty-nine days in ice cream. It may live even longer than this. It is not killed immediately by freezing and if infected water is used for making ice, or infected milk for ice cream, some of the typhoid bacilli may survive in the frozen product for some weeks. Impure ice or ice cream may, therefore, be real sources of danger.

The bacilli may enter the body through the mouth, by means of infected food or drink, such as water or milk containing the germs, food that has been handled by persons with the bacilli on their hands, raw vegetables for which sewage has been used as a fertilizer, or shellfish

which have grown in water polluted with sewage. They appear to pass through the stomach uninjured, and multiply in the intestine, shortly afterward passing through the intestinal wall, and thus getting into the blood stream.

Fig. 51.—Typhoid ulcers of the intestine as they appear in the second week of the disease. The intestine has been opened and we are looking at the inside. There may be serious hemorrhage from these ulcers. If the ulcer breaks through to the outside of the intestine, peritonitis will occur. (From MacCallum, Text-book of Pathology.)

The bacilli appear in the circulating blood in the first week of the disease. Typhoid is really, therefore, at first a septicemia, although later on, ulcers of the small intestine are practically always present (Fig. 51).

Typhoid bacilli begin to appear in the stools in the latter part of the disease and by the second week are present in enormous numbers. Billions may be passed in a single movement. The bacilli usually decrease during convalescence and finally die out. In about 11 per cent of patients, however, they continue for eight to ten weeks, and in 2 to 4 per cent they persist indefinitely. The first group are *convalescent carriers*, and the second group *permanent carriers*.

The bacilli appear in the urine about the fifteenth day of the disease, often in great numbers. They may continue for weeks, months, and in rare cases for years. There are thus urinary as well as fecal typhoid carriers.

How Typhoid Is Spread.—The source of infection is the feces and urine of the typhoid patient. Each case comes from a previous case or from a carrier; that is, the bacilli from the excretions of the first case are in some way, often hard to trace, taken into the mouth of the second patient.

The ways in which the disease is spread are by actual cases, carriers, flies, water, milk, and other foods.

1. *Contact with Patient.*—Typhoid is frequently spread by direct contact with the patient. This is one of the ways in which nurses and members of the patient's family may contract the disease; that is, they soil their hands while caring for the patient and neglect to wash them before going to meals, or they put their fingers in their mouths. If a nurse contracts typhoid while nursing a typhoid patient, it is at least strong evidence that she has been careless. Other examples of direct transfer of the bacilli come readily to mind:

a convalescent handles a piece of food and passes it on; a laundress handles clothing soiled with typhoid excretions; the mother of the family may have to nurse the patient and prepare the family meals, going to and fro between the sick room and the kitchen.

Contact cases are preventable. The greatest danger is in the early stages of the disease before the diagnosis has been made and disinfection of the excretions begun. Some cases of typhoid are very mild, showing nothing more than a little fever with intestinal disturbance and diarrhea. Unless typhoid is suspected, no precautions are taken, and there is ample opportunity for spread of the infection. We have already seen how large is the part of mild and unusual cases in spreading scarlet fever, and they are important also in typhoid, as well as in most other infectious diseases.

2. *Carriers* are extremely important in the spread of typhoid. Carriers have been reported who had had the disease as long as sixty-four years before they were discovered. The source of the bacilli in the feces is probably the gall-bladder, in which the organisms may sometimes continue to live and multiply as comfortably as in a culture-tube in the incubator. From the gall-bladder they are carried to the intestine with the bile. There is no certain way known at present to prevent a patient from developing into a carrier. There is also no successful method of curing carriers, although various kinds of treatment have been tried.

Carriers are a continual source of danger if they have anything to do with the preparation of food or milk, and many epidemics have been traced to them. The history of such an epidemic, which occurred in a California town a few years ago, illustrates what may

happen. A large number of typhoid cases broke out in a certain town within a few days of one another. It was found that all the patients had attended a certain supper about three weeks previously, and the one dish of which they had all eaten was creamed spaghetti. The woman who had contributed this to the supper had had typhoid many years before, and examination of her feces by the State Board of Health proved that she was still a carrier. This woman had been a boarding house keeper for many years and a number of cases of typhoid had developed among her boarders. In this particular case she had contaminated the spaghetti with typhoid bacilli from her fingers, while preparing it. It was baked in a large pan. It has now been shown by experiment that when large dishes of food or big pieces of meat are cooked for only thirty to forty minutes in the oven, the heat often does not have time to penetrate to the center. The center may become warm, but not sufficiently hot to kill bacteria. So, in this case, the organisms in the center of the mass had not been killed by the heat, but on the contrary had multiplied as if they had been in a culture-tube in the incubator. There were 93 cases of typhoid altogether, including the persons infected from the carrier and those which developed from contact with the first cases. About 10 people died.

The number of carriers in a community depends on the number of typhoid cases. Where typhoid is frequent, carriers are numerous and vice versa. The vast majority of typhoid carriers are never discovered. Only those are known who have been proved to be the cause of other cases of the disease. When the source of infection of typhoid cases is traced, as all health

departments try to do nowadays, the part played by carriers is found to be increasingly important. Probably more than one-third of all cases are due to them. Many of the cases in which the source of the infection cannot be traced are doubtless due to undiscovered carriers. The carrier is the most important single factor in the spread of typhoid, and the hardest to control.

3. *Flies* can act as distributors of typhoid bacilli. Typhoid cases are most numerous in the fly season. These insects contaminate their feet with the typhoid feces, then crawl over food, depositing the bacilli on it, or drop into milk and inoculate it with typhoid bacilli which may multiply there as if it were a culture tube. In screened and sewered communities, flies are probably not an important means of spreading the disease, but in the country, where there are unsanitary privies and no screens, flies may be an important factor. The same is true in military camps and unscreened wards for untidy mental patients.

4. *Milk* and other foods contaminated by actual cases or by carriers or flies account both for many scattered cases and for numerous epidemics. As has been said, the typhoid bacillus grows rapidly in milk without changing its appearance or taste. The germs may get into the milk from the hands of the dairyman or milkman, in case he or any of his family have typhoid, or from washing the cans or bottles in infected water, or from using milk bottles in the typhoid patient's room. The most extensive typhoid epidemic of this century occurred in 1927 in Montreal and was believed to be due to an infected milk supply. In this epidemic there were 4755 cases of typhoid fever and 453 deaths. It seems that for some reason the sanitary precautions

failed to function properly for a time and the result was this appalling loss of life. Too much stress cannot be laid upon the proper control of public milk supplies. Had the milk been properly pasteurized before delivery or consumption, there would have been no epidemic.

Epidemics have also been traced to *ice cream* made from milk containing typhoid bacilli.

5. *Water* polluted with sewage used to be the most frequent source of typhoid. Within the last twenty years, however, practically all American cities have provided themselves with good water supplies, and the greater part of the typhoid in cities is now due to other causes than water. In the country districts and in villages, on the other hand, polluted water still accounts for many cases of typhoid. Wells and privies are too often situated near together and the feces are frequently washed by rains or tracked by animals over the ground and into an open well. The bacilli may also be carried through the soil, into the well with underground seepage and streams (Fig. 52).

In spite of the precautions taken and the advice given, epidemics of water-borne typhoid still occur. The water may be contaminated in various ways. There may be some trouble or carelessness at the purification plant, so that the water is distributed without disinfection. A typhoid patient living near a stream which forms part of a city water supply may be responsible for many cases in a community a long distance away. A celebrated epidemic in a Pennsylvania town was caused in this manner. A man living beside a mountain stream, which supplied a town a number of miles away, had typhoid in November. His excretions were thrown, without disinfection, into an earth closet. In

the spring, after a thaw, an epidemic of typhoid suddenly broke out in the town below and was traced to the water supply, and finally back to the single typhoid patient on the mountain. There were 1104 cases in the epidemic and 114 deaths. The bacilli in this case remained alive over the winter and were washed into the stream during the spring thaw.

Typhoid bacilli do not multiply in water, as they do in milk, but they can remain alive in it for some time.

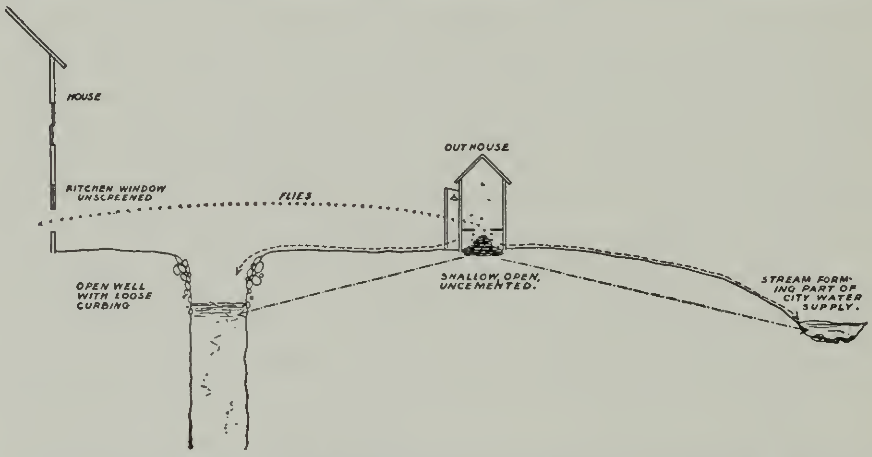


Fig. 52.—Diagram showing how an unsanitary outhouse can be a source of contamination for a city water-supply, a household well, and a kitchen.

Diagnosis.—The diagnosis of typhoid is made in the *early stages* of the disease by means of a *blood culture.* The diagnosis may be made in this way only during the first week, since after seven or eight days, the bacilli disappear from the blood. Ox bile obtained from the slaughter-house is used in the culture, as it is favorable for the growth of typhoid bacilli and unfavorable for other germs. (Possibly this explains the growth of typhoid bacilli in the gall-bladder of carriers.) Later in the disease the bacilli may be cultivated from the stools. The culture is purified by spreading a drop of feces on

plates of agar, mixed with certain substances which inhibit all but typhoid and colon bacilli, and clearly differentiate these two, incubating twenty-four hours and then selecting a well isolated colony. Bacteria from this colony are cultivated in broth and examined microscopically. Later on their ability to ferment various carbohydrates is tested. (See Table I on page 192.)

Carriers are similarly detected by finding the bacilli in cultures from their feces.

Widal Reaction.—As has been explained in a previous chapter, invasion of the body by bacteria causes the body to respond by forming antibodies. In typhoid fever, the antibodies most easily demonstrated are *agglutinins* which clump the bacteria. In most cases of typhoid an attempt is made to demonstrate the presence of these specific agglutinins in order to confirm the diagnosis. The test is named after the French physician Widal, who discovered it.

The test is done by either the microscopic or the macroscopic method. In the former, a drop of a broth culture of known typhoid bacilli is mixed with a drop of the patient's diluted blood serum and examined under the microscope. The bacilli are at first seen swimming around actively, each one separate, but if the test is *positive*, within fifteen or twenty minutes their movement stops and they gather into clumps (see Fig. 53). This is called agglutination and is due to antibodies in the patient's blood called *agglutinins*. The agglutinins do not appear in the blood until almost the second week of the disease or later. This is a good example of how slowly antibodies appear in active immunity (Chapter VIII). The Widal reaction, therefore, cannot be used for the early diagnosis of typhoid, but it is useful in the later stages.

When the macroscopic method is used, larger and measured amounts of a suspension of typhoid bacilli and of different dilutions of the patient's serum are mixed in test tubes. The agglutination is visible to the naked eye, as a settling of the bacilli to the bottom of the tube (Fig. 29).

Fig. 53.—A positive Widal reaction as seen under the microscope. Most of the typhoid bacilli have collected in clumps. A few are still free. Before the beginning of agglutination, the microscopic field would resemble Plate I, Fig. 1. (Wright and Brown.)

The Widal reaction is also positive in *carriers* and *persons who have been injected* with dead typhoid bacilli (typhoid vaccine) for the prevention of the disease, as will be described later. A "positive Widal reaction" means, therefore, that the person either *has typhoid at the present time*, or *has had it*, or *has been immunized against it*. The reaction is very reliable and is much used; but if positive, care must be used in interpretation.

The Agglutination Test for Suspected Typhoid Bacilli. A similar test is used in identifying any unknown bacilli which may be isolated from a stool specimen. In this test a pure broth culture of the *unknown bacterium* isolated from the patient is mixed with a little *known*

typhoid serum to see whether the bacteria in the culture are agglutinated by the serum. This is called an *agglutination test.* It is just the reverse of the Widal test. Both tests depend on the presence of the proper antibody in the serum. If the bacteria are agglutinated, they must be typhoid bacilli. If they are not agglutinated, they are some other organism, since the serum contained agglutinins only against the typhoid bacilli. Other specific agglutinating sera may be used to see if the unknown bacterium is some other species such as paratyphoid or dysentery bacilli. Known specific agglutinating sera of various types are kept in the laboratory for testing bacteria from various sources.

B. paratyphosus A (*Salmonella paratyphi*) **and B. paratyphosus B** (*Salmonella schottmülleri*). **Paratyphoid Fever.**—Paratyphoid bacilli resemble typhoid bacilli in general characteristics (*para* means *like*) and cause fevers similar to typhoid but usually milder. Fatal paratyphoid infections however, not infrequently occur. The organism most often associated with food infections (*Salmonella enteritidis*) very closely resembles the paratyphoid bacilli and is, indeed, generally spoken as one of the paratyphoid organisms. It may cause severe gastroenteritis and sometimes epidemics with high mortality. Other names for *Salmonella enteritidis* are "the *Gaertner bacillus*" and *B. enteritidis.* Cows and steers are sometimes infected with these bacilli and if the flesh is eaten improperly cooked, infection from the meat is apt to occur.

The paratyphoid bacilli are spread chiefly by carriers and food. Many animals such as rats and mice, may be carriers of paratyphoid-like bacilli and so cause infections of food. Human carriers also sometimes occur.

CHAPTER XVI

B. TYPHOSUS (Continued). B. DYSENTERIAE

Immunization against typhoid and paratyphoid fevers: results; duration of immunity—*B. dysenteriae*—Bacillary dysentery: transmission; vaccination against; serum treatment—Spirillum cholerae asiaticae.

Immunization against Typhoid and Paratyphoid Fevers.—It is possible to produce *artificial active* immunity to typhoid and paratyphoid fever by giving injections of dead typhoid or paratyphoid bacilli. (See Chapter VIII.) The treatment consists in giving three doses of vaccine one week apart, the first of 500,000,000, the second and third of 1,000,000,000 bacilli. The injections are usually followed within twenty-four hours by considerable swelling and soreness of the arm. There are sometimes general symptoms—headache, nausea, and a rise in temperature—but these are not serious and they pass off in a day or so. The most suitable time for giving the inoculations is late in the afternoon. The person should keep quiet for the rest of the day and should not undertake hard work on the following day. Saturday afternoon is a good time to give the injections.

The vaccine usually given consists of a mixture of typhoid bacilli and the two varieties of *paratyphoid bacilli*, called A and B. It is possible to protect against both typhoid and paratyphoid at the same time with scarcely any increase in the reaction.

Results of Antityphoid Immunization.—The reduction of typhoid fever where typhoid vaccine has been used on a large scale, as it is in the army, has been truly marvelous. *It is one of the great successes of preventive medicine.* Antityphoid immunization was made compulsory in the United States Army in 1911, and in the World War it thoroughly justified itself. In former wars typhoid had been responsible for more sickness and deaths than all the wounds of battle. In the Spanish-American War (1898–99) one in every seven men developed typhoid, and one in every seventy-one died from it. During the World War, in which our troops were often exposed to extremely unsanitary conditions, there were only 156 deaths due to typhoid or paratyphoid among the 4,000,000 United States soldiers. If there had been as high a death-rate from typhoid as in the Spanish War, there would have been 68,164 deaths.

Duration of Immunity.—Following the injections of vaccine, the cells of the body produce antibodies which protect against typhoid bacilli. *This simple treatment gives a high degree of protection against typhoid fever for a considerable time.* It is impossible to say just how long the immunity lasts. It begins to fail after a time, but some degree of protection remains for a number of years. In the army the men are reinoculated every three years. The protection depends also on the number of doses; less than three are insufficient to immunize. Human beings, like animals, differ in their ability to manufacture antibodies in response to the stimulation of the vaccine. Some produce them abundantly, others only in small amounts. The strain of bacilli used in making the vaccine is also of great importance, since some

strains have greater powers than others to cause the production of protective antibodies.

Inoculation is not at any time an absolute protection against typhoid, since a recently inoculated person may develop the disease if he receives an immense dose of virulent bacilli. The treatment will, however, protect

Fig. 54.—Dysentery in a child. Extensive ulceration of the colon. (From MacCallum "Text-book of Pathology.")

against the moderate doses which one is likely to get in ordinary chance infection. An inoculated person must not relax any precautions that he would otherwise take. An immunized nurse should be as scrupulously careful about washing her hands and taking all other measures to protect herself as if she were not inoculated.

B. dysenteriae (Eberthella dysenteriae).—There are several varieties of dysentery bacilli. The first one of the group was discovered by a Japanese physician, Shiga, in 1898. A second type was discovered by an American physician, Flexner, in 1906; and there are now a number of other types known. Like the other members of the group of Gram-negative intestinal bacteria under discussion, dysentery bacilli grow well in the laboratory and are easily killed by heat and disinfectants. They remain alive outside the body on food, cloth, or in the soil for only a short time as compared with the typhoid bacillus. They grow in milk without changing its appearance or taste. They may be differentiated from other bacilli in the group by the characters shown in the table on page 192, and also by the agglutination test.

The bacilli cause ulcers of the large intestine (Fig. 54), and the most intense and painful diarrhea. The feces contain blood, mucus, and pus. The organisms do not occur in the blood, like the typhoid bacillus, but they are limited to the large intestine. *They form a powerful poison which causes the prostration and loss of weight associated with the disease.* The bacilli are cast off in large numbers in the bowel movements, and may persist for months in convalescents.

Bacillary Dysentery.—This is an infectious disease caused by the different varieties of the dysentery bacillus. The disease appears in two forms: first, as it is seen in adults, and second, as a severe form of summer diarrhea in babies.

Transmission.—The disease is spread in much the same manner as typhoid fever, that is, by fingers, flies, milk, foods, and by any articles which have been in

contact with the bowel movements of a previous case. In many instances the severe form of the infection in infants is contracted from a grown person or an older child in the family, who may be suffering merely from a mild diarrhea. The same bacillus which causes only a diarrhea in an adult may give rise to a fatal dysentery in a baby. Water-borne epidemics of dysentery are rare.

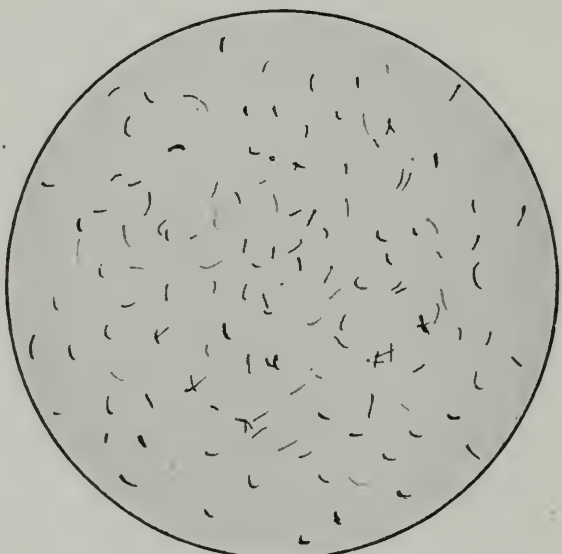


Fig. 55.—The cholera spirillum.

Vaccination against dysentery appears to have little value. **Serum treatment,** however, appears to be fairly successful. A serum is used which is active against the several types of dysentery bacillus, and is therefore a good example of a *polyvalent* serum, (see Chapter VIII).

Spirillum Cholerae Asiaticae.—The cholera spirillum is in many respects very much like the typhoid bacillus. It is, however, curved spirally (Fig. 55). It is Gram-negative, motile, and nonspore-bearing, and easily killed

by boiling, pasteurization and good disinfectants. It is spread about in exactly the same manner as the typhoid bacillus. It causes Asiatic cholera, the chief symptoms of which are intense diarrhea, prostration, emaciation, and usually death, unless treatment be started in time.

Cholera is always present in India and other Eastern countries. In the past it has many times started from the East and swept over almost the entire earth, somewhat as influenza did in 1918. During the nineteenth century there were five such great epidemics, some of which reached the United States.

Prophylactic vaccination with killed cultures of the cholera spirillum is of distinct value, and has been used on a large scale in India. The principles and methods are similar to antityphoid inoculation.

CHAPTER XVII

THE PREVENTION OF TYPHOID AND PARATYPHOID FEVER AND DYSENTERY[1]

Incidence of typhoid fever—Measures for the prevention of typhoid and paratyphoid: those concerned with the patient; control of carriers; sanitary measures; individual prevention; antityphoid and paratyphoid immunization—Prevention of infant dysentery.

Incidence of Typhoid Fever.—The reduction in typhoid fever in the United States during the last twenty-five years has been one of the great triumphs of preventive medicine. For a long time typhoid stood fourth among the causes of death, following tuberculosis, pneumonia, and cancer. It has now been reduced to a much lower place, although there are still about 60,000 cases a year in this country, and in 1929 there were 4,854 deaths from it.

Typhoid most frequently attacks young people. One-half of all cases occur between the ages of fifteen and twenty-five, and about one case in ten results fatally. The disease is more frequent in the country than in cities. This is because city water supplies are better; cities are sewered; milk supplies are generally pasteurized; typhoid patients are usually taken care of in hospitals, so that there is less opportunity for the infection of others; and in cities carriers are more easily discovered and controlled.

The measures for the prevention of typhoid and paratyphoid fever are:

[1] For a more advanced discussion see Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

(1) Those concerned with the patient and the disinfection of his excretions;

(2) The control of carriers;

(3) The sanitary control by the public health authorities of water and milk supplies, sewage, and food handlers;

(4) Protection against the disease by the use of antityphoid and paratyphoid vaccines;

(5) The measures that each person should take for his own protection.

These will be considered in turn. It may be pointed out that all rules for the prevention of typhoid fever apply also to paratyphoid fever and dysentery.

1. **Measures Concerned with the Patient.**—The place where typhoid, paratyphoid and dysentery bacilli can be dealt with most effectively is at the bedside as they come from the patient and before they are scattered. This is the prevention of the diseases at their source. The disinfection of the excretions is the special duty of the nurse, who has a great responsibility not only for the welfare of the individual patient, but for the protection of the community. The feces and urine must be disinfected, as well as everything that could possibly be contaminated with them; as bed linen, clothing, and wash water. It is advisable for the nurse to wear rubber gloves and a rubber apron when waiting on patients with these diseases, or disposing of the excretions. The gloves and apron should of course be disinfected each time after use. The patient's dishes should be boiled.

The patient must be isolated as a case of infectious disease; no visitors should be allowed in the sickroom. The milkman is notified, as a rule, by the health department. The person who does the nursing should not

prepare food for any one else, or even for herself. Typhoid and dysentery cases should, if possible, be treated in hospitals.

The greatest danger of infection is not, however, from the *known* typhoid, paratyphoid, or dysentery patient, but in the early stages before the diagnosis has been made, and from the cases which are so mild that they are never diagnosed. *Every patient having any intestinal disturbance associated with fever should be put on typhoid precautions until a diagnosis can be made.* This measure would prevent the spreading of dysentery and paratyphoid fever, as well as of typhoid. *It is better to isolate unnecessarily than too late.*

No typhoid, paratyphoid or dysentery convalescent should be taken out of isolation until three consecutive specimens of feces and urine, taken at intervals of six days, have been found negative for the causative bacilli. The first specimens should be sent when the temperature is nearing normal. Even with repeated examinations under the most favorable conditions some carriers will be missed. (See Chapter on Collection of Specimens.)

2. **Control of Carriers.**—The control of carriers is the most difficult part of the antityphoid program. The greater number of the carriers discovered are those who have infected other persons through food or milk. They are most often cooks, housewives, boarding-house keepers, nurses, or milk-handlers. A carrier who has nothing to do with the handling of food or milk is not so likely to be a danger to other persons. The most important point in regard to carriers is their *occupation. Health departments in many states keep proved carriers under supervision.* The co-operation of the carrier is enlisted, and definite rules and restrictions are laid down,

the most important of which is that the carrier shall not engage in any occupation requiring the handling of food and milk; that the feces shall be disinfected and also the hands after using the toilet. The health authorities keep in touch with carriers by means of visits and reports.

3. **Sanitary Measures.**—The frequency of intestinal infections in any community depends to a large extent on sanitary conditions; that is, those relating to water and milk supplies and the disposal of feces. These infections, typhoid, paratyphoid, and dysentery, offer a marked contrast to the group of diseases carried by the secretions from the mouth, as pneumonia, whooping-cough, and measles. These latter are as frequent in clean communities as in dirty, since sanitary measures have no effect on their prevalence.

The reduction of typhoid in cities in the last twenty-five years has been due in great part to the provision of clean water supplies and the pasteurization of milk. Most of the typhoid in large cities today comes from contact with cases or from carriers.

A **pure water supply** is the first sanitary necessity for getting rid of typhoid, for if a water supply is polluted with sewage the population will frequently get doses of typhoid bacilli. If wells are used, they should be at a long distance from outhouses, should be dug deep, the sides tightly cemented to keep surface water out, and the tops covered (Fig. 52). Laboratory examination of the water should be made at least each spring and fall.

The second necessity is the **proper disposal of sewage** to prevent it from getting into water supplies. In cities and towns where there is a sewerage system, all the sewage can be treated at one plant by scientific methods and made entirely harmless and inoffensive. If a

community is too small to afford a sewerage system, it can provide sanitary privies, which will prevent contamination of wells and the spread of bacteria by flies and animals. The health departments of a number of states have, in recent years, been carrying on an energetic campaign for sanitary privies, with the result that there has been a marked reduction in rural typhoid.

The **pasteurization of milk** is essential for reducing typhoid and other infectious diseases. This has already been discussed. Milk supplies in the large cities, where practically all the milk is pasteurized, are only rarely the cause of typhoid. In smaller cities, on the other hand, pasteurization is less general, and in small towns all over the country, very little milk is pasteurized. Under these conditions, infected milk still accounts for considerable typhoid.

Many cities require an **examination of food handlers** in public eating places, in order to exclude persons having communicable diseases.

4. **Individual Prevention.**—For one's individual protection certain precautions should be taken. If one suspects that the water supply is polluted, drinking-water should be boiled. The common household water-filters are untrustworthy, and so are some of the bottled waters which are popular in cities where the water supply is doubtful. Campers, picnickers, and vacationists should be careful about their drinking-water. Milk should be pasteurized in the home unless one is sure that it has been produced and distributed under clean conditions. It is better to avoid taking milk in public eating places unless it is served in the original bottle and has been pasteurized. Finally, every one should be protected by immunization.

Antityphoid and Paratyphoid Immunization.—*Wherever antityphoid and paratyphoid immunization has been carried out among groups of people, as in the Army and Navy, institutions, and schools of nursing, it has practically eliminated these infections.* The persons for whom antityphoid immunization is most necessary are:

First, those especially exposed to the disease on account of their work. This includes doctors, nurses, medical students, attendants, orderlies, and hospital employees. *There is no excuse for medical and nursing schools not requiring immunization of their students, or for doctors and nurses not keeping up their immunity.* Yet in Massachusetts, in 1926, about thirty nurses in a certain hospital had typhoid, and of these one died. None of them had been immunized against typhoid. Statistics from a number of large hospitals show that typhoid was formerly from two to eight times more frequent among those who come into close contact with patients, that is, doctors, nurses, and orderlies, than among the general population; and also that they are more likely to have the disease in a severe form, with more complications and a higher mortality, because they get the bacilli absolutely fresh from the patient in which condition *all* germs are more virulent.

Second, all members of families in which there is a case of typhoid should be protected at once. *No one who is not immunized to the disease should be allowed to nurse a typhoid patient.*

Third, groups of persons who live in close contact. This includes persons in state hospitals, prisons, institutions for children and young people, residential schools, army camps, ships, and colleges. Immunization of all persons connected with state hospitals is

particularly important. Several outbreaks in such institutions have been traced to carrier-patients who worked in the kitchens or dining rooms. An epidemic which occurred in a large maternity hospital a few years ago was caused by the cook, who was a carrier.

Fourth, all persons who travel should be inoculated, as they must often partake of food and drink of doubtful origin. This group includes vacationists, traveling salesmen, missionaries, and persons who are going to foreign countries.

Fifth, the general public should be immunized when there is an epidemic, or in places where typhoid is prevalent. *The more persons who are immunized against any disease, the sooner will it disappear.* This applies not only to typhoid but to diphtheria, smallpox and, in fact, to any disease against which it is possible to protect.

The value of antityphoid and paratyphoid immunization has been known for more than twenty years. It is offered free by state and city health departments. It has practically eliminated the disease in the Army and Navy in time of peace, and in institutions in which every person has been treated. The inconvenience is trifling in comparison with the protection afforded. Nurses cannot afford, for their own sake, to neglect this measure for their protection. In addition it is their duty, as persons professionally interested in preventive medicine, to do all in their power to popularize the use of antityphoid immunization.

Antityphoid vaccination does not take the place of other measures against typhoid, but is an addition to them. It will be impossible for some time to come to get rid entirely of sources of typhoid infection, particularly of

carriers, and antityphoid immunization protects against infection which we cannot avoid.

Prevention of Infant Dysentery.—The methods of preventing the spread of *adult* dysentery are in general the same as for typhoid and paratyphoid fever. *The prevention of infant diarrhea,* however, depends first on encouraging breast feeding; second, on teaching mothers correct methods of caring for babies and of preparing their food; and third, on the general improvement of milk supplies and pasteurization of all milk. The breast-fed baby not only gets milk which is especially suited to its needs, but it gets it in a sterile condition. When a baby is artificially fed, the milk should be pasteurized (unless certified milk is used) and *protected from flies.* Nursing bottles and nipples should be sterilized by boiling before each use; the feedings should be prepared by a person with clean hands, and the bottle, after it is prepared, kept away from flies and dirt. Babies should be kept away from any one having an intestinal disturbance. *A person who is caring for a child with summer diarrhea should not prepare food for other children or for adults.* The baby's crib and carriage should be screened during the fly season. The diapers of infants suffering from diarrhea should be sterilized at once. Old linen, which can be burned when it is soiled, should be used if possible.

Dysentery is liable to spread in children's hospitals and infant asylums, so that such patients should be isolated with strict precautions.

The baby welfare clinics have also been a strong factor in diminishing dysentery in infants. The public health nurses connected with these clinics visit the homes and teach the mothers correct methods of preparing the baby's food and the general care of the child.

CHAPTER XVIII

THE GRAM-NEGATIVE PATHOGENIC BACILLI (Continued) GROUPS II, III, AND IV

B. influenzae—B. pertussis: whooping cough; vaccine—*B. bronchosepticus—B. ducreyi—B. melitensis;* undulant fever.

Group II: *associated with the respiratory tract.*

B. influenzae (Hemophilus influenzae) is one of the smallest bacilli (see Plate I; Fig. 3). It is very particular in its growth requirements, flourishing only on media containing hemoglobin or certain unknown substances which can be extracted from potatoes or yeast. It grows only at body temperature. It is not motile and is extremely delicate, dying soon outside the body. It is, of course, easily killed by heat and disinfectants.

It is found in the noses and throats of many normal people and is transmitted in droplets in sneezing and coughing. It is found in many inflammatory conditions of the respiratory tract, such as bronchopneumonia, and has been found in pure culture in the blood of patients dying of other diseases. Its relation to influenza is extremely doubtful. It may sometimes cause meningitis.

B. pertussis (Hemophilus pertussis).—Whooping cough is caused by a small bacillus usually called B. pertussis, discovered in 1906 by two Belgian workers, Bordet and Gengou. It is sometimes called the Bordet-Gengou bacillus. It produces an inflammation of the trachea and bronchi (Fig. 56), and consequently is found in the sputum, saliva, and nasal discharge. The bacillus

grows slowly and with difficulty outside the body. It has the same fastidiousness about its media as the influenza bacillus. It also is Gram-negative and nonmotile and forms no spores. It is transferred directly from person to person by droplet infection during coughing, and by articles soiled with nose and mouth secretions. A spray of sputum and saliva may be thrown out to a distance of 4 or 5 feet during the

Fig. 56.—Whooping cough. Minute bacilli present in masses between cilia of two cells lining the trachea: In the lower part of the picture are seen the nuclei of three epithelial cells of the tracheal lining. Above the nuclei is the cytoplasm of the cells, and on the surface are masses of B. pertussis. × about 1500. (Mallory and Horner.)

violent attacks of coughing. It is possible to obtain an almost pure culture of pertussis bacilli if a petri plate containing a suitable medium for growth be held before the mouth of a coughing patient.

Whooping cough begins with the symptoms of an ordinary cold. It is most infectious during the first few days of the actual disease, when the bacilli are present in the sputum in enormous numbers. The bacilli may linger for some time after convalescence, so that by many it is thought best to keep a child isolated for several weeks after the cough has stopped.

Whooping cough, like measles, is a more serious disease than is generally realized on account of the other infections which complicate or follow it, the most important of which are bronchitis, pneumonia, and tuberculosis. Whooping cough is really responsible for many fatal cases of bronchitis and pneumonia in young children. It caused about 7000 deaths in the United States in 1925. Ninety-seven per cent of the fatal cases occur under five years, and 50 per cent under one year.

Whooping Cough Vaccine.—In the last few years a vaccine made of killed whooping cough bacilli has been used to some extent for the prevention of the disease. There is some difference of opinion as to its value, but most of the reports are favorable. It appears to have considerable value in preventing the disease. Epidemics in institutions have been stopped by immunizing all the children as soon as the first case appeared. The vaccine is of less value for the cure of the disease than for its prevention. Nevertheless, in some cases it does reduce the severity of the fits of coughing and shorten the course of the disease. The treatment is entirely harmless, and it seems probable that in the future it will be used on a larger scale for both prevention and treatment. The vaccine is furnished free by some health departments.

B. bronchisepticus (Alkaligenes bronchisepticus).—This is a very small Gram-negative bacillus causing distemper in dogs and symptoms in children very much like whooping cough. Its relation to human infection was discovered by Brown at Johns Hopkins, in 1926. It is transmitted in the same way as B. pertussis. Rabbits, dogs and other pets may act as *carriers*. It is

differentiated from B. pertussis and B. influenzae in being motile and able to grow on ordinary media. It appears very probable that many cases thought to be genuine whooping cough are in reality due to B. bronchisepticus. It is also possible that the difference of opinion regarding the value of vaccine made from the pertussis bacillus may be due to the fact that many of the diseases treated with B. pertussis vaccine were really being caused by B. bronchisepticus, a different germ.

Group III. B. ducreyi (Hemophilus ducreyi).—The bacillus of Ducrey is very much like the influenza bacillus and B. pertussis, and is therefore included here although it causes no infection of the respiratory tract, but a disease of the external genitalia and adjacent parts of the skin, called *chancroid* or *soft chancre*. The disease is transmitted by sexual intercourse and by the use of articles contaminated with the pus and serum from lesions. It spreads over the surfaces and erodes the tissues of the genitalia. The disease yields quite readily, as a rule, to vigorous disinfection of the affected parts and to personal hygiene.

Group IV. B. melitensis (Brucella melitensis).—*Undulant fever*, the disease caused in man by B. melitensis, has probably existed in many parts of the world, including the United States, for a long time, but only recently has it come into nation-wide prominence in this country. In 1929, 1,305 cases were reported, but there were doubtless a great many more which were not diagnosed or reported. The causative agent was first discovered by Bruce, a British scientist, who was investigating the disease as it occurred in Malta. Hence the organism is called Brucella melitensis. Bruce discovered it originally in

goats' milk. Since then, however, several varieties have been found in other parts of the world, causing somewhat different diseases, according to whether the organism is of the variety which infects cattle, hogs, or human beings.

Varieties.—The variety infecting cattle causes abortions in these animals, and is called *Brucella melitensis* (*Var. abortus*). Formerly it was known as *B. abortus.*

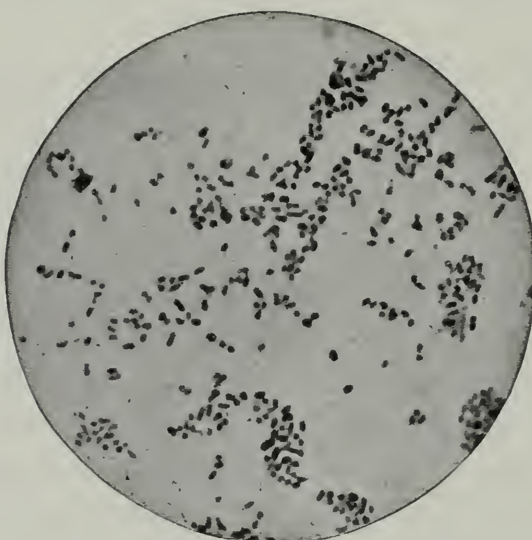


Fig. 57.—Brucella melitensis. Carbol fuchsin; × 1200. (Hicks.)

The variety infecting hogs is called *Brucella melitensis* (*Var. suis*); and that infecting goats, *Brucella melitensis* (*Var. melitensis*). Although bacteriologists are not in complete agreement about these names, most of them agree that the three varieties exist, that they can be differentiated by laboratory tests, and that they cause undulant fever in man.

Characteristics (of all varieties).—The organisms (Fig. 57) are very small, round or oval, nonmotile, nonencapsulated, nonspore-bearing, Gram-negative

bacilli. When first isolated, they grow very slowly. An infusion of liver, in the form of broth or agar, slightly acidified, is the most favorable medium for them. The bovine variety will grow at first only in a special atmosphere containing an excess of carbon dioxide. The other forms grow well aërobically. They do not ferment carbohydrates in the ordinary way.

Undulant Fever.—The disease in man is frequently characterized by a long preliminary stage lasting days or weeks, during which there is an increasing weakness and later, backache, stiffness of the joints, progressive loss of weight, and a series of indefinite symptoms. The incubation period may be as long as a month or as short as four or five days. There are severe night sweats and remittent daily fever, or repeated undulatory attacks of fever, each lasting several days, with remissions between the waves. In its milder forms, which are frequent, the malady may be regarded by the victim as "grippe" or "intestinal flu." A small percentage of the cases are acute and fatal, but the great majority, after continuing for months, eventually recover.

Transmission.—During the disease, the organisms invade the blood stream. In infected cattle and goats, they are found in the milk. In all infected animals, they are present in the tissues, and for this reason the disease is particularly common among employees of slaughter-houses. The organisms may pass through the skin or enter through the mouth. Persons who drink unpasteurized milk or use unpasteurized butter from cows which have not been carefully tested to rule out the disease, are in danger of contracting the infection.

Diagnosis.—*An agglutination test*, performed almost exactly like the Widal test, is one of the best methods of diagnosis. The serum of patients, used in this test, agglutinates the Brucellae in considerable dilutions.

Prevention.—The disease may be prevented by using only certified raw milk and milk products, or by using only pasteurized dairy products, and by carefully avoiding any infected animals. As long, however, as there are animals in which the infection exists, the persons handling the live or slaughtered stock or the raw dairy products are in danger of contracting the disease.

Vaccines have been found of little value in prevention, and there is no special method of cure. Nursing procedures are similar to those used in typhoid fever from the standpoint of preventing the spread of the disease to the nurse and other persons.

CHAPTER XIX

THE GRAM-POSITIVE PATHOGENIC BACILLI

Aërobic and anaërobic bacteria—Life without free oxygen—Anaërobic methods—*B. welchii*—Gas gangrene—Serum treatment of B. welchii infections—*B. tetani:* toxin; antitoxin—*B. botulinus.*

The Gram-positive bacilli to be discussed in this book have been listed and grouped in Chapter XV. It will be noticed that they are classified as *Aërobic, Facultative,* and *Anaërobic.* These terms are related to the oxygen requirements of the organisms.

Aërobic and Anaërobic Bacteria.—Some bacteria can multiply only in the presence of free oxygen or air. Such bacteria are called *strict aërobes* or *strictly aërobic* bacteria. The only examples of this group which are discussed in this book are *Bacillus anthracis* and *Corynebacterium diphtheriae.*

The term *anaërobic* as applied to bacteria means that they can multiply in the absence of air (free oxygen). Some bacteria have the faculty of multiplying either in the presence or absence of air and are called *facultative anaërobes.* Examples of facultative anaërobes which are discussed in this book are the Gram-negative bacilli which inhabit or infect the intestine. There is also a group of bacteria which can multiply *only where air (free oxygen) is absent.* The bacteria of this type are called *strict anaërobes.* Examples of strict anaërobes discussed in this chapter are *Clostridium tetani, C. welchii* and *C. botulinum.*

Life without Free Oxygen.—It seems strange that any creature can live and multiply without the free oxygen of the air. It is generally believed that oxygen is necessary to life. So far as is known this is perfectly true. Bacteria which grow without *free* oxygen are able to utilize the so-called "combined oxygen" *i. e.*, that which is chemically combined in various forms, such as

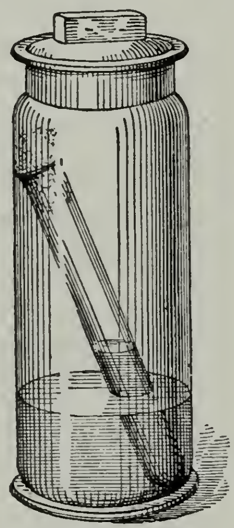


Fig. 58.—An arrangement for the cultivation of anaërobes. The jar contains the oxygen-absorbing mixture of pyrogallic acid and 10 per cent caustic soda. The inoculated tube is placed in the jar, and a close-fitting cover put on. Buchner's method. (MacNeal.)

carbohydrates. By means of their enzymes these bacteria cause decomposition of various oxygen-containing compounds, thus securing for themselves the first necessity of life—oxygen.

Anaërobic Methods.—*Facultative* anaërobes have the enzymes necessary to anaërobic existence, but they are not affected by the presence of free oxygen of the air. *Strict* anaërobes, on the other hand, are unable to multiply in the presence of free oxygen; hence in cultivating and studying them special precautions must be taken to

exclude air from the cultures. This is accomplished by a variety of ingenious devices, some very simple and others quite complicated. The methods used are called *anaërobic methods.*

One method is to pour sterile vaseline or paraffine in a thick layer over the surface of the culture. This excludes air but is inconvenient to work with. Another method consists in placing the cultures inside a jar which is capable of being tightly sealed and has a tube leading into it that also can be tightly closed. The air is sucked out of the jar by a vacuum pump and the tube is then closed. The air may be replaced by some other gas, such as carbon dioxide, nitrogen, or hydrogen. Sometimes a little or all of the air is left in the jar, but some substances which absorb oxygen, like a mixture of pyrogallic acid and strong alkali, are put into the jar before sealing it (Fig. 58).

It is impossible in a small book to describe many of the great number of anaërobic devices. It is only necessary to remember that they are all designed to remove and exclude oxygen from the cultures of bacteria.

In the present chapter we shall discuss first the *strict anaërobes,* and then the only sporebearing strict aërobe which is a dangerous pathogen, namely *B. anthracis.*

B. welchii (*Clostridium welchii*).—This organism is the most important representative of a group of anaërobic, Gram-positive spore-bearers which cause the condition of *gas gangrene* in traumatic wounds. They are found in the soil and have in common the characteristics of forming large amounts of gas in the tissues about the wound, and of producing enzymes which dissolve the tissues with which they come in contact.

B. welchii is a short, thick bacillus with rounded ends (see Plate II; Fig. 5). The spore is formed near the center and appears like a hole in the bacillus unless stained by special spore stains. When cultivated in milk B. welchii produces much acid, which clots the milk.

Fig. 59.—Growth of C. welchii in milk. "Stormy fermentation." (N. MacL. Harris prep.) (From Jordan "General Bacteriology.")

Gas is then formed and the clot is torn to shreds and the plug may be blown from the tube. This process, called "stormy fermentation" (Fig. 59), is one of the most characteristic cultural appearances of the Welch bacillus.

As the organism is often found in the normal intestinal tract of man and animals, it is easy to understand

why its spores should be widely scattered in the soil. Wounds which become contaminated with soil, especially manured soil, may readily become infected with B. welchii and the related bacilli, which are similarly distributed.

Gas gangrene is liable to develop in a deep, dirty wound, such for example, as a bullet wound or a nail-puncture which is not properly cleaned out and treated. When the spores of the B. welchii group of organisms lodge in a deep wound, they there find ideal conditions for growth. It is warm, moist, there is dead tissue for food and, because the wound is deep, the air is excluded and strict anaërobes can grow. Gas is formed. The bubbles press on blood vessels, and the tissue dies for want of blood and becomes gangrenous and swelled and distended with gas, because the bacilli soon invade the dead tissue. Thus the condition spreads and may destroy a whole limb in a comparatively short time.

Gas gangrene is not, properly speaking, an infectious disease, since it cannot be transmitted from one person to another, and since the organisms do not invade healthy tissue but live only in the dead tissues of the wound or gangrenous process. Gas gangrene can be prevented by proper and prompt treatment of wounds. *Deep, dirty* wounds are to be carefully cleaned, opened as much as practicable, drained, irrigated, and made to heal from the bottom up. Exposure of the depths of the wound to air, as far as possible, prevents the growth of the anaërobes. All dead tissue should be cut away.

Serum treatment of B. welchii infections is quite successful. Such serum is often given a patient who is admitted to the accident ward with a wound which shows possibilities of gas gangrene. It is an *antitoxic*

serum, since B. welchii secretes an exotoxin, which is absorbed from infected wounds. The serum which was developed by Bull and Pritchett in 1918 at the Rockefeller Institute, New York City, was used with good results during the World War.

B. tetani (Clostridium tetani).—The second strict anaërobe listed in the table in Chapter XV is *Bacillus* (*clostridium*) *tetani*. Like B. welchii, this bacterium is found in the normal intestinal tract, especially of horses. Here it does no harm. It is very widely distributed, however, in the soil, especially in street dirt and manured farm lands. Like B. welchii, it is dangerous to man only when it gains entrance to some deep, dirty wound where there is dead tissue. In street and farm accidents and war wounds, B. tetani and the gas gangrene group are usually found together. The tetanus bacillus, as we have mentioned above, is a spore former. The spore, situated at *the end* of the bacillus, gives the organism a "drumstick" appearance. (See Plate II; Fig. 6.) When protected from sunlight and other injurious influences the spores may remain alive and virulent for many years. One investigator produced tetanus in an animal with bacilli from a splinter of wood infected eleven years before.

When the bacilli grow in a wound, they produce the deadly disease tetanus. If, however, they are taken into the intestinal tract they are entirely harmless. This is a striking illustration of the fact mentioned in Chapter V, that the pathway by which an organism enters the body is of great importance in determining whether or not disease will occur, and that the majority of bacteria can cause an infection only when they enter through their own particular route.

Tetanus Toxin.—*The tetanus bacillus causes the disease by means of a powerful exotoxin which it produces. Tetanus toxin* is one of the most deadly poisons known; the injection of 0.000,005 cc. of a broth culture of the bacillus (which contains the toxin) is sufficient to kill a mouse. The harmful action of tetanus toxin is due to its action on the *brain* and *spinal cord.* This action is shown by the convulsions to which death from the disease is due. The toxin reaches the brain and cord by traveling up the motor nerves in the vicinity of the wound. It is also distributed through the blood.

Antitoxin.—This is obtained in the same way as diphtheria antitoxin; that is, by injecting horses with broth in which tetanus bacilli have grown, and which contains their toxin. The *curative* value of this antitoxin is much less than that against diphtheria, but it has immense value in *preventing the development of the disease. It is, therefore, a general practice to give a prophylactic or immunizing dose of* 500 *to* 1500 *units to patients who have wounds in which tetanus bacilli are liable to develop.* Such immunization to tetanus is an excellent example of the use and value of *passive immunity.* During the World War tetanus was very common until every wounded man was given an immunizing injection as soon as he came under medical care. The result of this first-aid treatment was the elimination of much tetanus as a cause of death among the wounded. The same treatment is now generally given for wounds due to accidents.

After tetanus toxin has affected nerve tissue the antitoxin cannot neutralize it; hence, the great importance of giving the antitoxin as soon after the injury as possible. The poor results obtained with antitoxin given

after symptoms of the disease have developed are largely due to this fact. When symptoms of the disease are present, the antitoxin is given both intravenously and intraspinally.

Tetanus is also prevented by the proper treatment of wounds. Every wound, however slight, should be thoroughly cleansed; it should be fully opened and every particle of foreign material removed. All *deep wounds* containing *dirt* should receive special attention.

B. botulinus (Clostridium botulinum).—The botulism bacillus resembles the Welch bacillus very much in appearance, in being a Gram-positive, spore-bearing anaërobe, and in being found in the soil. It differs culturally in forming no gas, in being motile, and (probably) in not being able to grow in the human body. The latter statement raises the question:—How, then, does it produce disease?

The botulism bacillus can grow well in such places as the center of large sausages and in canned foods which are not too acid, such as canned beans, meat, or corn. If spores of the organism are enclosed in the cans and are not killed by the "processing" or autoclaving at the canning factory, they may germinate. The bacillus gives off an extremely powerful *toxin*, which, when swallowed, nearly always proves fatal. The appearance, taste or odor of the food may give absolutely no hint of the presence of the toxin.

Protection against botulism is easy because the toxin is *destroyed by a few minutes boiling.* For absolute safety therefore, *all canned foods should be held at boiling for a few minutes before eating.* As a matter of fact, however, there is little danger now-a-days from eating canned foods. The canners themselves take excellent

precautions against botulism by cleanly preparation and thorough autoclaving of all canned goods. *Any cans which show bulging ends should be discarded, as well as any cans showing evidences of fermentation, or acid or gas formation.*

There is an efficient *serum* which may be used for the *prevention* of botulism. As in tetanus, however, after the symptoms have appeared, the patient's chances of recovery are slight.

CHAPTER XX

B. DIPHTHERIAE

B. diphtheriae: toxin; diagnosis; virulence; Diphtheria: transmission; clinical cases; missed cases; carriers; infected milk—Preventive nursing—The therapeutic use of antitoxin—Immunity to diphtheria—Passive immunity—Active artificial immunity; toxoid—The Schick test—Active immunization of children; of nurses—Deaths from diphtheria.

B. diphtheriae (Corynebacterium diphtheriae).—The diphtheria bacillus was discovered in 1883–84 by two German physicians, Klebs and Loeffler, and is sometimes spoken of as the "Klebs-Loeffler" bacillus. These bacilli have a characteristic appearance especially when stained with *methylene blue.* They are Gram-positive, but the Gram stain is seldom used to stain these organisms. When seen with the microscope after being stained with methylene blue, they are observed to be curved and to have dots at the ends and often bars through the middle. In laboratory cultures after they are ten hours or more old they assume curious shapes resembling clubs (coryn—from the Greek word for "*club*"), dumb-bells, and exclamation points. (Fig. 60.) The bacilli grow well in the laboratory on certain media, so that it is usually possible to tell in twelve hours from the time a throat culture is started whether or not diphtheria bacilli are present. The substance on which they grow best is Loeffler's medium, a mixture of dextrose beef broth and beef serum (obtained from the slaughter-house), which has been coagulated by heat.

In moist material, the bacillus is easily killed by heat since it forms no spores, but it stands drying and exposure to light better than most nonspore-bearing disease-producing organisms. It may live quite a long time in saliva deposited on dishes, tableware, toys, etc. Bits of membrane may be thrown out in coughing and dry on the furniture or floor. In these the bacilli may

Fig. 60.—Diphtheria bacilli. A, Solid-staining forms, showing "parallelism"; B, Barred form; C, Club-shaped form; D, Beaded form; E, "Dumb-bell" form. Magnified 600 times.

remain alive for several months and be distributed as dust. The bacilli are easily killed by disinfectants.

Toxin.—*The diphtheria bacilli, in an ordinary case of diphtheria, are not spread throughout the body, but remain limited to the throat, where they form a very powerful exotoxin which is taken into the blood and injures the various organs, especially the heart, nervous system, and kidneys.* This toxin is more powerful than the strongest drugs. The amount produced in a patch of membrane the size of the thumb nail, in the throat, may be suffi-

cient to cause death. The symptoms of the disease are due to this toxin.

Diagnosis.—The bacilli are found in the throat in all cases of diphtheria, and often in the saliva and nasal

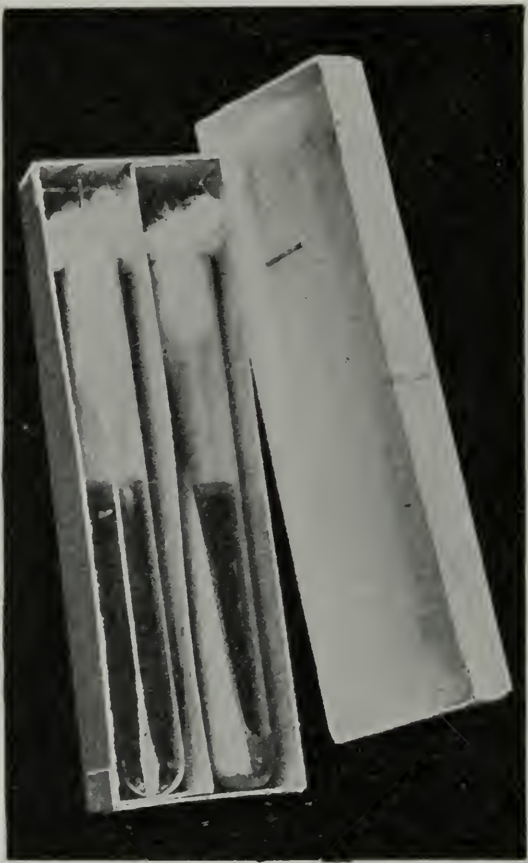


Fig. 61.—A Board of Health outfit for diphtheria diagnosis, consisting of a box containing a culture-tube and a tube of Loeffler's medium. The swab is rubbed over the patient's throat and then immediately over the surface of the medium, so that no time is lost in starting the culture. (McFarland.)

discharge. The diagnosis is made by taking a small amount of material from the throat on the end of a sterile swab. The swab is then rubbed on the surface of Loeffler's medium, and this is incubated for twelve to

twenty-four hours. Stained smears are then made and examined with the microscope. Outfits for making such cultures are furnished by all health departments (Fig. 61). The nurse frequently has to get these outfits, and before taking them she should look at the serum to see that it is still fresh and moist, as the bacilli will not grow on dry serum.

Virulence.—The question of virulence of the bacilli is of the greatest importance in connection with diphtheria carriers. Not all diphtheria bacilli can cause the disease; that is, not all are virulent. Those which cannot cause the disease are harmless. It is possible to tell whether or not a particular culture is virulent by injecting it into a guinea pig, and all health departments are prepared to make this test, called a "virulence test." Guinea pigs are especially susceptible to virulent diphtheria bacilli. Certain peculiar changes are produced in them, especially hemorrhages in the adrenal glands, which can be recognized by those especially trained in such work.

Diphtheria starts as an acute inflammation of the throat caused by the diphtheria bacillus. When the bacillus grows on the tonsils and walls of the throat, it causes the usual form of diphtheria. It may grow also in the nose, producing nasal diphtheria, and in the larynx, causing what used to be known as "membranous croup," but what is now generally called *laryngeal diphtheria.* The bacillus forms a grayish-white covering or *membrane* where it grows, which is characteristic of the disease.

Children under five years are the most liable to contract diphtheria, and it is more likely to be severe in them than in older children or in adults. From 80 to 85

per cent of all deaths from the disease are in children under five years. The number of cases of diphtheria and also of other contagious diseases of children rises rapidly in the fall, because bringing the children together in school increases opportunities for contact infection, and also because fall and winter are the seasons of indoor living and of slight infections of the nose and throat, which allow diphtheria bacilli to settle down and start the disease.

Transmission.—Diphtheria is spread by means of the *saliva* and *nasal discharge*, either by direct contact, as in kissing, or by coughing into another's face, or, as is frequently the case with children, by articles which go directly from the mouth of one child to that of another, as pencils, chewing gum, or drinking cups. Fingers may also carry the bacilli.

The methods by which the disease is transmitted are:

1. **Clinical Cases.**—2. **Missed cases,** that is, cases of true diphtheria in which the diagnosis is not made because the symptoms are mild or unusual. Some slight sore throats are due to the diphtheria bacillus, but this can be proved only by culture. Hence a culture should be made from every case of sore throat, especially in schools and institutions, as one cannot always tell simply by looking at a throat whether it is a case of diphtheria or of ordinary tonsillitis, caused by hemolytic streptococci or some other organisms. In children's wards the nurse should be on the watch for nasal discharges, especially those which irritate the nostrils or are tinged with blood, as these may be due to the diphtheria bacillus. A throat and nose culture is usually made as a matter of routine on each

new patient admitted to a children's ward. Recognized cases of diphtheria are usually fairly well isolated, because every one is afraid of the disease; but no precautions are taken in the missed cases, and they go around scattering the bacilli.

3. **Carriers.**—Diphtheria carriers were the first kind discovered, and much of our knowledge of carriers in general has come from the study of diphtheria. *There are three kinds of carriers of diphtheria* bacilli: (a) convalescents; (b) contacts; (c) those who are not known to have had any association with the disease.

Convalescents usually get rid of the bacilli in a few days or weeks, but in some cases the bacilli may remain in the throat and nose for a long time after the patient has recovered. In about 5 per cent of the cases they persist for two months, and in about 1 per cent they remain indefinitely. Most health departments require *two or three negative cultures* (*that is, cultures which do not show the diphtheria bacillus*) *from both the throat and nose, taken at intervals of twenty-four to forty-eight hours, before a patient may be released from isolation.*

The second kind of carriers may be the schoolmates of the pupil who has been taken sick with diphtheria, members of the family, or the nurse who has had the care of him. These people are more dangerous than the patient or convalescent, because they go about freely; and it is they who are the hardest problem in the control of the disease, on account of the difficulty of detecting and of isolating them. The number of carriers of this kind depends on the strictness of the isolation of the patient, and the care taken in nursing and disinfection. It has been found that when no precautions are taken to isolate the patient, from 50

to 100 per cent of the members of the family become carriers; whereas, when such precautions are taken, only about 10 per cent become carriers. Carriers keep diphtheria alive in the schools, in which it is spread by various childish practices, such as putting pencils in the mouth, using each other's handkerchiefs, passing around candy, and taking turns on chewing gum. Healthy carriers do not as a rule keep bacilli for more than a few days or a few weeks.

When a case of diphtheria has appeared in a family, a school, or an institution, cultures are taken from the throats and noses of all persons who have been in contact with the patient. If any carriers are found, they are isolated until their cultures are negative. Carriers must observe the same precautions as are taken in actual cases of diphtheria to avoid scattering the bacilli by means of the saliva and nasal secretion.

The third class of carriers, those who have had no known contact with diphtheria cases, are discovered accidentally when throat cultures are made as a routine.

Any abnormal condition of the nose or throat—as adenoids or enlarged tonsils—favors the persistence of the bacilli both in healthy carriers and in convalescents. *It also favors the lodgment of diphtheria bacilli and the development of the disease.*

Carriers of bacilli which cannot produce the disease are not dangerous; the carriers of virulent bacilli are those who must be controlled. The bacilli found in the throats of diphtheria convalescents and of contacts are practically always virulent. These are, therefore, the dangerous carriers. The bacilli found in the throats of persons who are not known to have had any contact with the disease are frequently not virulent.

Therefore, if isolation involves much inconvenience for these persons, the health department should be asked to find out whether or not the bacilli are virulent; if they are not, the carrier may be released.

The question of what to do about carriers of virulent bacilli is both important and difficult. Child carriers should of course be kept at home and away from other children, and precautions taken in the care of the secretions. If, however, the carriers are wage earners, it would be unjust, as well as practically impossible, to keep them away from work unless it involved some special danger to others, as the handling of milk and food, the care of children, teaching, or nursing. In other cases the carriers are warned of the danger of spreading the bacilli, given definite directions about disinfecting their dishes and avoiding contact with others, and are allowed to continue their work. The health department keeps carriers under supervision to make sure that instructions are carried out. Every carrier should be required to have the nose and throat put in good condition, as that is the quickest and surest way to get rid of the bacilli.

4. **Infected Milk.**—As it was pointed out in Chapter X, the diphtheria bacillus grows well in milk, and does not change its appearance or taste. The milk may be contaminated somewhere in its course from the cow to the consumer by means either of a healthy carrier, a person with a very mild unrecognized diphtheria who keeps on with his work, or by a convalescent who has returned to work while still carrying the bacilli. The bacilli are usually transferred to the milk by means of the hands, but they may occasionally come from milk bottles which have been returned from

a home in which there is a case of diphtheria, and have not been sterilized before being refilled. Pasteurization kills diphtheria bacilli, but the *milk may be infected after it has been pasteurized.* Diphtheria bacilli can resist freezing for short periods, hence ice-cream made from infected milk may cause epidemics.

Epidemics of diphtheria due to milk are not rare. *The characteristics of a milk epidemic of any disease are that the cases break out all at once; that they are all on the route of one milkman, or among the customers of one dairy or firm; and that a majority of the patients are children.* This is true also of epidemics of scarlet fever and of typhoid caused by milk. The two most important agencies in spreading diphtheria are, however, the missed cases and the healthy carriers. Together they keep the disease going in a community.

The preventive nursing of a case of diphtheria centers around the disinfection of the secretions from the nose and throat and of articles soiled by them, and the prevention of carriers. The principles are the same as for any disease spread by the saliva and nasal secretion, and they need not be repeated here. If the patient is treated at home, one person should be responsible for the nursing, and patient and nurse should be isolated from the rest of the family. With intelligent nursing and disinfection at the bedside, the danger of caring for a diphtheria patient at home is not so much that members of the family will catch the disease, but that they may become *carriers.* It is advisable, therefore, whenever possible, to treat diphtheria patients in a special ward or hospital. After the patient has been released from isolation *terminal disinfection* of the room should be carried out.

The Therapeutic Use of Diphtheria Antitoxin.—*Diphtheria antitoxin was one of the earliest discoveries made in the study of immunity, and it is one of the greatest*

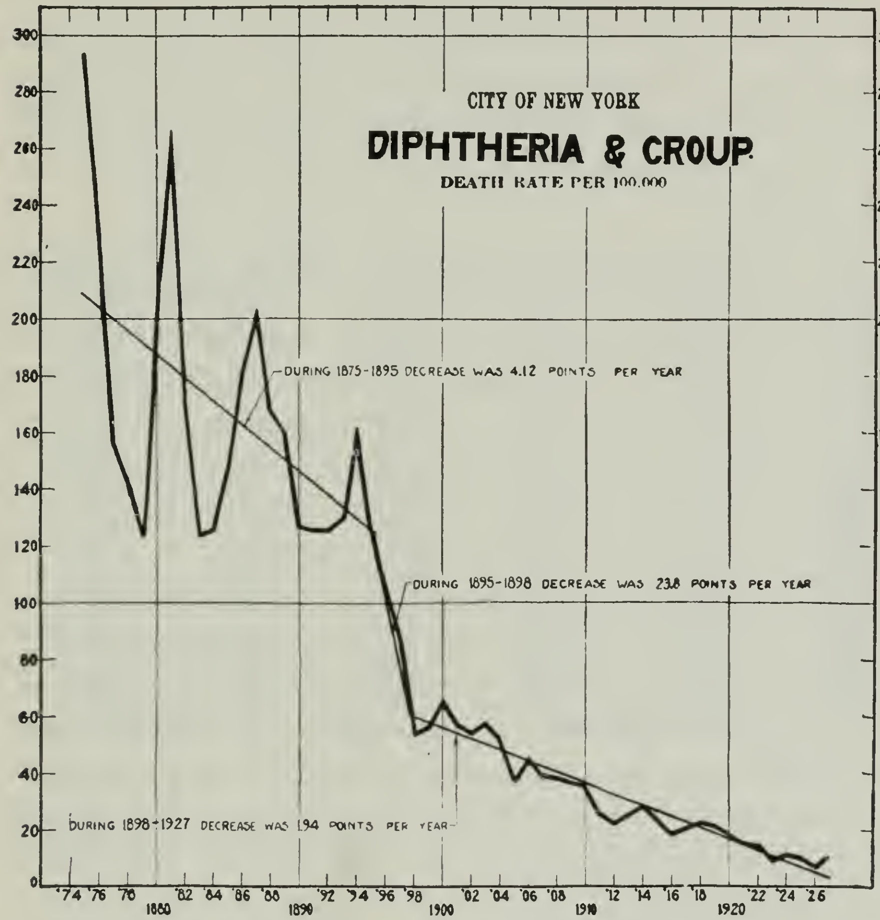


Fig. 62.—The mortality from diphtheria in New York City since 1875. The figures on the vertical scale represent the numbers of deaths annually per 100,000 population. The peaks in the pre-antitoxic era correspond to epidemics. The immunization of children on a large scale with toxin-antitoxin began about 1921. (From Bolduan "Public Health and Hygiene".)

triumphs in the whole history of bacteriology. Antitoxin first came into use about 1894, and it has saved an enormous number of lives. Diphtheria used to be a

common and fatal disease. In New York City in 1887 (before the days of antitoxin) it caused about 10,000 deaths annually (Fig. 62) while since its use has become general the rate has dropped so that in 1926 there were only 476 deaths. A good part of the decrease in diphtheria incidence is due to preventive measures such as active artificial immunization with toxin-antitoxin mixtures, as discussed farther on in this chapter.

For therapeutic purposes the dosage of antitoxin is determined by the seriousness of the symptoms, the stage of the disease at which treatment is begun, and the age of the patient. The sicker the patient and the later the stage of the disease, the larger must be the dose. In desperate cases antitoxin is given intravenously. *The antitoxin combines with the toxin circulating in the blood and renders it harmless.*

The *curative power* of diphtheria antitoxin is measured in antitoxin units. The *"unit" of antitoxin* is the amount which counteracts a certain standard amount of toxin. This is tested on guinea pigs. The unit is used for expressing the potency of antitoxin just as minims and drachms are for ordinary medicines. A strong diphtheria antitoxin contains from 800 to 1200 units to the cubic centimeter.

If sufficient quantities of antitoxin are given early in the disease practically every case of uncomplicated diphtheria should recover (Fig. 63). *The success of antitoxin treatment depends on counteracting the toxin by antitoxin before the poison has had the opportunity to injure the body cells.* The overwhelming importance of giving antitoxin early cannot be too strongly emphasized. *A few hours lost* in beginning

treatment may make all the difference between life and death, or recovery with paralysis or a damaged heart and kidneys.

Immunity to Diphtheria.—*Immunity to diphtheria depends on the presence of antitoxin in the blood.* As long as a person has antitoxin he will not develop diphtheria, even though the bacillus may lodge in his throat. A large proportion of adults and a small proportion of

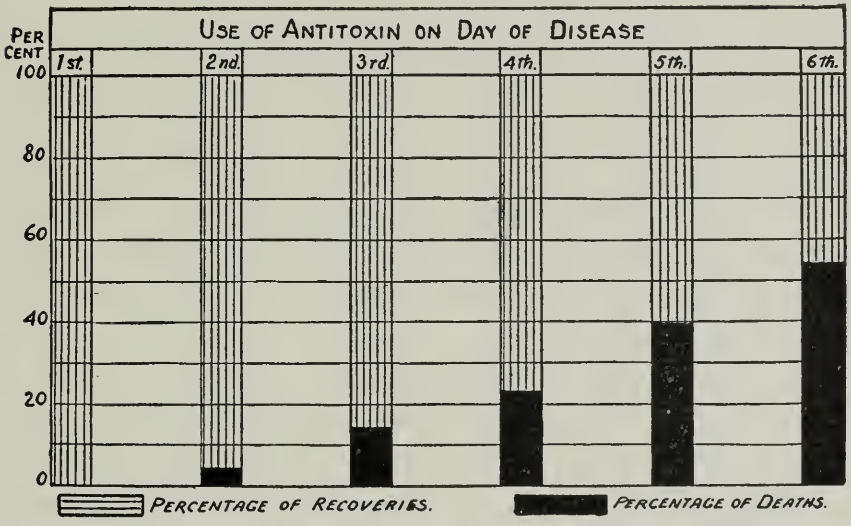


Fig. 63.—Showing how the chances of recovery from diphtheria are increased by the early use of antitoxin. (From Reprint No. 778 from the Public Health Reports by Schereschewsky and Dyer.)

children have antitoxin naturally in their blood, and are therefore immune to the disease, even though exposed to it. This is called *natural immunity. Artificial immunity,* both *passive* and *active,* is also possible.

(A) Passive Immunity.—*A small dose of antitoxin* (500–1000 *units*) *will prevent the development of diphtheria in those exposed to the disease.* This is called a *prophylactic* or *preventive dose,* and the protection given by it lasts only about four weeks. This is a good

example of *temporary passive* immunity. Formerly a preventive injection was given to those intimately exposed to a case of diphtheria, as the nurse and members of the family; but now that we have a method of producing *lasting* immunity to diphtheria, antitoxin is given only to those who are in immediate danger of developing the disease, like children, and the others are immunized by the slower method of toxin-antitoxin.

The use of antitoxin is sometimes followed by "*serum sickness.*" This has been discussed in Chapter IX. A few days after antitoxin has been given a rash appears often resembling the hives; in other cases there may be a diffuse redness, a rise in temperature, and pains in the joints. These symptoms are not serious. They are not due to the antitoxin, but, as has been said, it is a manifestation of *hypersensitiveness* or *allergy* to the proteins in horse serum.

(B) **Active Artificial Immunity.**—It is possible to stimulate the human body artificially to produce antitoxin by the injection of toxin. One method consists in the injection of a very small amount of diphtheria toxin mixed with enough antitoxin so that the toxin is not dangerous. The antitoxin has nothing to do with the production of the immunity, but it prevents the toxin from being irritating. The toxin stimulates the body to produce antitoxin *over a long period of time.* Three 1 cc. doses of the toxin-antitoxin mixture are given subcutaneously at intervals of one week (Fig. 64). *The immunity appears slowly,* in two to three months, but once established *it appears to be lasting.* The procedure is absolutely harmless. Infants have no symptoms from it, but in adults the reactions are sometimes similar to those following antityphoid

inoculations. The procedure is spoken of as *toxin-antitoxin treatment*, or "T-A-T" for short. *The immunity produced by it is active (slowly developing and permanent), in contrast to the passive immunity given by antitoxin (immediate but transient).*

The student will note that this method of producing active artificial immunity against diphtheria in human beings is exactly the same as that used in the immunization of horses for the production of antitoxin (Fig. 33), and the results are similar. The application of the principle to the prevention of diphtheria was later in development than the use of antitoxin for curative purposes. Immunization with toxin-antitoxin mixture was introduced into this country in 1913 by Dr. William Park of the New York City Department of Health.

Toxoid.—A substitute for toxin-antitoxin mixture in immunization consists in the use of diphtheria *toxoid*, sometimes called *anatoxin*, which is prepared by treating the toxin with formaldehyde and heat. Toxoid is less poisonous than the untreated toxin and is thought by many to be a more effective immunizing agent. It produces immunity more quickly than toxin-antitoxin mixture, and since no serum is used in its preparation, there is no possibility of sensitizing the person to horse serum.

Toxoid was introduced in Paris in 1924. It has been widely adopted and eventually it will probably replace toxin-antitoxin. The principles and methods of use are the same.

The Schick Test.—Not only is there a method of giving lasting resistance to diphtheria, but there is also a test for determining whether a person is susceptible; that is, whether he would develop the disease if exposed.

This is called the Schick test after the Viennese physician (Fig. 64) who first made practical use of it. *It depends on the fact* stated above *that some persons have antitoxin naturally in their blood.* It depends on *exactly the same principle which underlies the Dick test* in scarlet fever, is done in the same way and the same

Fig. 64.—Dr. Schick, Austrian scientist, who originated the Shick test, immunizing a child at one of the special diphtheria-prevention stations established in New York. (Underwood and Underwood.)

sort of reaction occurs. The test is performed by injecting into the skin an extremely small amount of diphtheria toxin (Fig. 65). If the person has no antitoxin in his blood, a small red area appears at the place of injection within twenty-four hours (Fig. 66). This is caused by the irritating effect of the toxin on the cells of the skin, which are not protected by

antitoxin. It is a *positive reaction* and means that the person is *susceptible to diphtheria.* If he has antitoxin in his blood, *the antitoxin counteracts the toxin injected, and the skin remains normal.* This is a *negative*

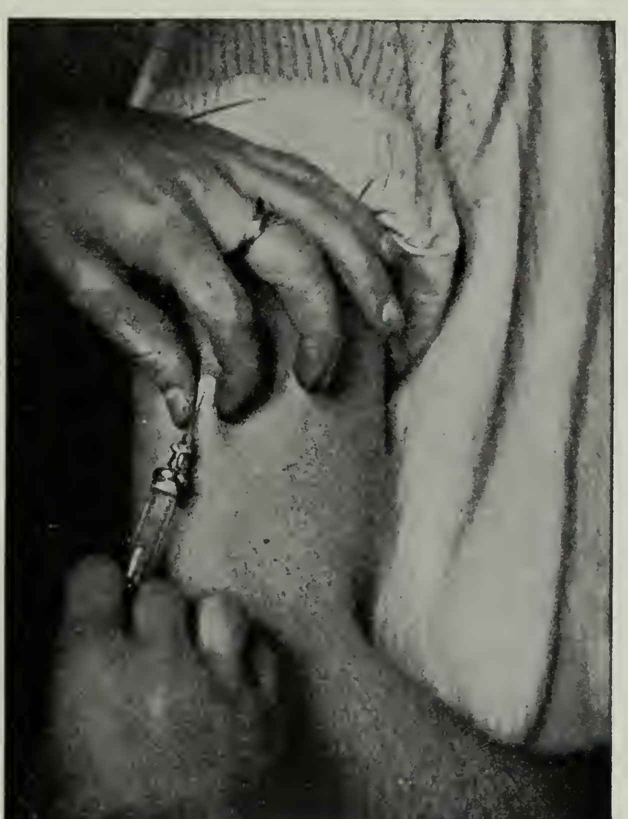


Fig. 65.—Method of giving an intradermal injection. The skin has been cleaned with alcohol and pinched up between the thumb and index-finger of the left hand; the needle (No. 26) has been entered *into* the epidermis and 0.1 cc. of fluid injected. Note the anemic area, indicating that the injection has been *intradermic.* (From Kolmer's "Infection, Immunity, and Biologic Therapy.")

reaction and shows that the person is *immune to diphtheria.* The test is harmless, painless, and leaves no scar.

Active Immunization of Children.—It is now practicable to protect *permanently* against diphtheria the

entire child population. Extensive campaigns are carried on by the health departments of cities throughout the country, with the object of immunizing every child. The treatment has passed the experimental stage, and in most cities has become a regular part of the preventive functions of health departments and of school medical work. There are several millions of immune children in the United States at the present time.

The protection of children of preschool age is even more pressing than that of the school population, because the frequency of diphtheria is greater among them, and a large proportion of the deaths occur at that period. The protection of the preschool group is now being undertaken through "well-baby" stations, playgrounds, day nurseries, and special clinics. If all children could be immunized at six months of age, there would be only a small fraction of the amount of diphtheria that there is at present. Health departments try to inoculate in summer all children who are to enter school in the fall.

Immunization of Nurses.—*It is scarcely necessary to say that every nurse should be protected at the beginning*

Fig. 66.—The Shick test for immunity in diphtheria. A well-marked reaction thirty-six hours after the intracutaneous injection of one-fortieth the minimum lethal dose of a diphtheria toxin diluted to 0.05 cc. The patient's blood contained no antitoxin. The brownish erythematous area with edematous infiltration of the subcutaneous tissues are characteristic of the reaction. A positive Dick test has a similar appearance. Both reactions have the same cause—the irritating effect of a toxin (scarlet fever or diphtheria) on the cells of the skin when the toxin is not neutralized by an antitoxin (scarlet fever or diphtheria) in the blood. Hence a positive reaction in each case means a susceptibility to the disease. (Reprinted from the *Amer. Jour. Dis. Children.*)

Fig. 66.—For explanation see facing page.

of her training, whether or not the course includes the care of contagious diseases. Of 380 nurses tested in a number of Massachusetts hospitals, 52.8 per cent gave a positive Schick reaction.

Deaths from Diphtheria.—*Diphtheria is today an absolutely preventable disease,* just as smallpox is; yet people still die from diphtheria. It is the most frequently fatal disease among children from one to three years of age. At present there are between 90,000 and 100,000 cases in the United States each year, and about one patient in every ten dies. The chief cause for this great and unnecessary number of fatal cases is that the doctor is not called until the child's condition becomes grave, and then it is too late for any amount of antitoxin to cure the disease. The parents of some of these children are simply ignorant; others belong to cults which do not believe in medical treatment. *Early diagnosis and prompt administration of antitoxin would prevent nearly all deaths from diphtheria.*

The fundamental way to meet the diphtheria problem is, however, to make the population permanently immune, instead of waiting for the disease to develop. By immunizing the children as fast as possible, a protected population will gradually grow up, just as we now have in some States a population protected by vaccination against smallpox. A good beginning has been made on immunizing children, and results are apparent in a reduction of the death-rate. The outlook is very hopeful. Diphtheria can be and will be eliminated.

CHAPTER XXI

BACILLUS TUBERCULOSIS

Mycobacteria—*B. tuberculosis:* characteristics; varieties—Tubercles—Tuberculosis; transmission; diagnosis—Tuberculous infection and the disease tuberculosis—Childhood infection—Tuberculosis, a family disease—Allergy in tuberculosis: the tuberculin test; methods—*B. leprae.*

Mycobacteria.—There is a group of organisms called mycobacteria (myco from the Greek for *mold*), which are considered to stand somewhat apart from most other pathogenic bacilli and to show characteristics which ally them to a more complex group of parasitic plants—the *molds.* It may be that the mycobacteria hold an intermediate position between the ordinary bacilli and the molds. This will be discussed further in Chapter XXIX.

The mycobacteria are slender rods which stain with difficulty but, as explained below, are *acid-fast;* hence they are often called the "acid-fast bacilli." They occasionally show branching forms which ally them to the molds. They grow slowly on media.

By far the most important member of the mycobacteria is the tubercle bacillus. A harmless variety of acid-fast bacillus is found on the external genitals. Other varieties have been isolated from butter, hay, and other substances.

B. Tuberculosis (Mycobacterium tuberculosis).—One of the most important discoveries in medicine was that of the tubercle bacillus, first seen and cultivated

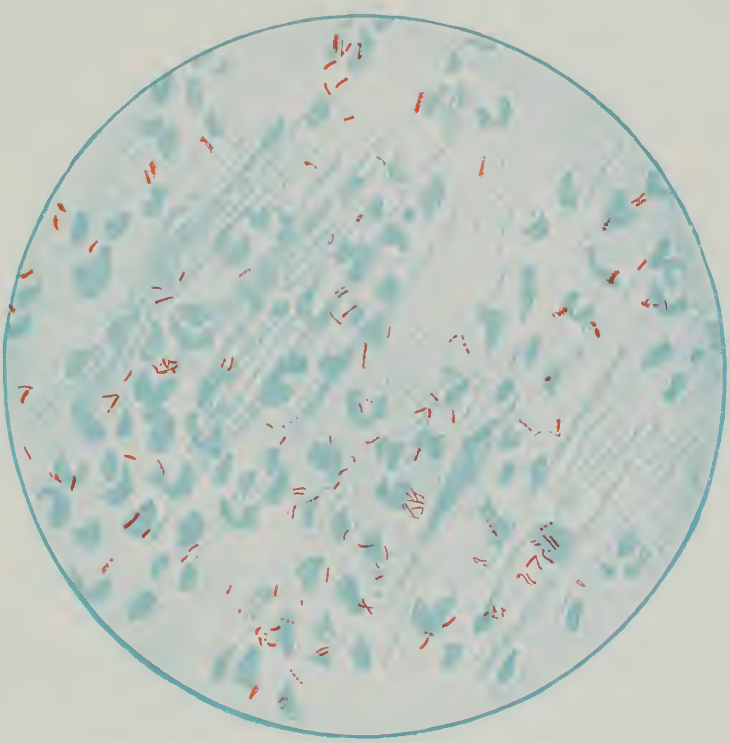


Fig. 67.—Tubercle bacilli in sputum, Ziehl-Gabbett; magnified 650 times. The bacilli have been stained red. The mucus and pus cells in the sputum are stained blue for contrast. Note the granular appearance of some of the bacilli, and their arrangements in clusters. The many bacilli pictured here are in a very tiny fraction of a droplet (Cornet and Meyer).

in the laboratory by Koch in 1882. For hundreds of years previously, however, it had been suspected that the disease was infectious. In 1865 Villemin produced tuberculosis in animals by inoculation with material from patients dead of tuberculosis, although he was unaware of the bacillus.

Tubercle bacilli as seen with the microscope, are slender rods, often curved and having a beaded appearance. They do not form spores. They are Gram-positive. The Gram stain, however, does not give as much information about them as some other methods. In fact, a special staining method is used, called the *Ziehl-Neelsen stain*, which is as follows:

1. The smear is prepared as usual.
2. Flood with a solution of carbol-fuchsin (a red dye) (formula found in the larger text-books).
3. Heat the slide gently so that the solution steams. *Do not allow to boil. Do not allow to dry.*
4. After about three to five minutes, wash off the stain.
5. Apply alcohol which contains 3 *per cent hydrochloric acid*, for a minute or two. Wash.
6. Counterstain with methylene-blue.
7. Wash and blot.

The *acid alcohol* removes the red fuchsin from *everything except the acid-fast* bacilli. These, then, retain the red stain while everything else appears blue (Fig. 67). The Ziehl-Neelsen stain is a *differential* stain just as is the Gram-stain, since it differentiates the acid-fast bacilli from other kinds. The reason for heating the slide is that the acid fast bacteria have a *waxy* cell wall. This must be softened so that the stain can soak in. Once in, it stays there in spite of the application of acid and alcohol.

The tubercle bacillus grows slowly in the laboratory, requiring about two weeks before its colonies are large enough to be seen with the naked eye. (Colonies of most other bacteria are visible in twenty-four hours.) It requires special media usually containing glycerine.

Fig. 68.—Culture of bacillus tuberculosis in flask of glycerine bouillon. The bacillus forms a heavy wrinkled covering on the broth. (From Hiss, Zinsser and Russell, "Text-Book of Bacteriology," D. Appleton & Co., Publishers.)

It grows well on medium made of eggs or the heated serum of dogs.

In spite of the fact that tubercle bacilli do not form spores, they are more resistant to heat, disinfectants, and drying than most disease-producing bacteria. In dried sputum which is kept in the dark they may live

from six to eight months. In particles of dried and powdered sputum which can float through the air as dust, they may remain alive for eight or ten days. They are also very resistant to dry heat, and in dried sputum can withstand a temperature of 200 F. for one hour. Exposure to sunlight kills the bacilli in a few hours.

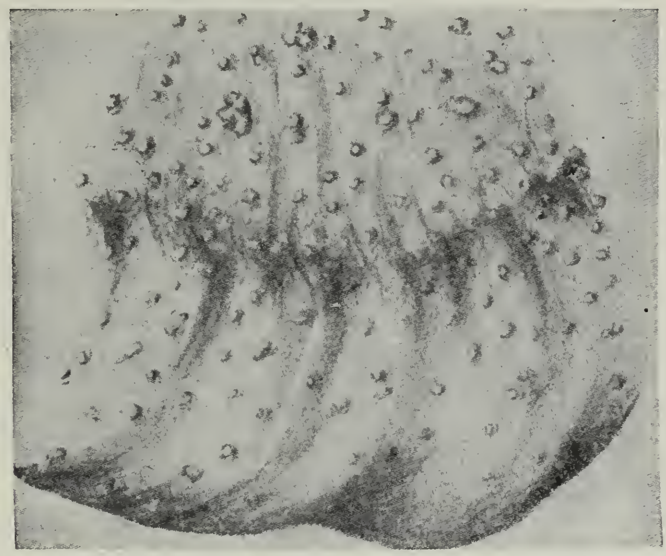


Fig. 69.—Tubercles of the peritoneal covering of the intestine and of the mesentery. About life size. (Ribbert.)

It is difficult to kill the bacilli in sputum by means of disinfectants because of their waxy membrane and because they are protected by mucus. Complete disinfection of sputum with 5 per cent carbolic acid requires five or six hours. Bichloride of mercury is unsatisfactory because it coagulates the sputum and therefore does not penetrate. Much the safest way is to collect the sputum in paper cups and burn it.

Varieties.—There are two chief kinds of tubercle bacilli. The first and more important is the human kind, which is spread from man to man. It is the cause

of pulmonary tuberculosis and of the larger proportion of all tuberculous infections. What has been said previously in this chapter refers to the human tubercle bacillus.

The second kind, the *bovine* bacillus, affects cattle as well as human beings. The two kinds of bacilli, human and bovine, can be differentiated by laboratory tests. If a cow has tuberculosis of the udder, the milk will contain the bacilli. Children may be infected by drinking the milk of tuberculous cows, and this method of infection accounts for a certain proportion of tuberculosis of the lymph glands of the neck and abdomen, and also of the bones in children. Pasteurization kills tubercle bacilli. Adults are not often infected with the bovine bacilli, but this kind is an important factor in the tuberculosis of children.

Farmers' organizations all over the country are coöperating with the United States Government in an effort to get rid of tuberculosis in cattle.

Tubercles.—Wherever tubercle bacilli locate in the body they cause a special kind of inflammation, different from that produced by other bacteria. We have seen that the diphtheria bacillus causes a characteristic inflammation in the throat, associated with a covering or membrane. The inflammatory reaction induced by the tubercle bacillus is called a *tubercle.* These tubercles are so characteristic that a diagnosis of tuberculosis can be made from them alone, even though the bacilli may not be found with the microscope. A single tubercle is a gray mass, the size of a pinhead or smaller, which feels hard to the touch (Fig. 69). Numbers or masses of tubercles usually occur together in an organ (Fig. 70). Unless the resistance

of the patient is sufficient to stop their progress, the bacilli inside of them may continue to grow, producing

Fig. 70.—Pulmonary tuberculosis. The lung has been cut through the center and we are looking at a section. The section shows masses of caseated tubercles. The cavities were formed by the softening of such masses, and the material was cast off as sputum. (From MacCallum, "Text-book of Pathology.")

further inflammation, enlarging the tubercles, and killing the tissue at the center. This dead tissue becomes coagulated into a cheesy mass, and when the process

has extended to this point *caseation* is said to have occurred. If the process continues, numbers of such caseated abscesses may encounter each other as they expand, finally fusing together to form one large, caseous mass.

The necrotic process often invades and breaks through the wall of a bronchiole, and then the caseous contents,

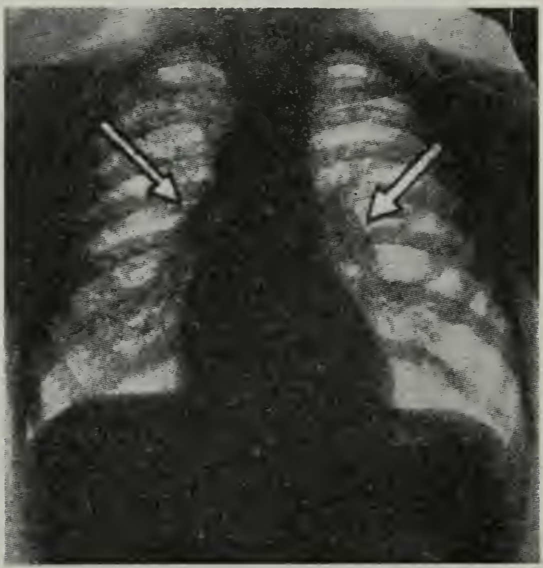


Fig. 71.—An x-ray picture of a child's chest, showing calcified tuberculous glands at the root of the lung. The shadows of the ribs and clavicles are easily recognized. Below, is the diaphragm. The central shadow is that of the heart and great vessels, and the lighter shadows, to which the arrows point, are the calcified glands. (Courtesy of the National Tuberculosis Association.)

along with numerous tubercle bacilli, are coughed up with the sputum. This is a very dangerous stage of the disease, for other people as well as for the patient.

If a tuberculous abscess breaks through the wall of a blood vessel, a *hemorrhage* occurs, which may prove fatal. Tuberculous sputum and the pus from tuberculous abscesses is made up largely of the dead and softened tissue of tubercles.

Tubercles frequently heal, in which case they become surrounded by thick envelopes of scar-like tissue, and lime salts may be deposited in them, *i. e.*, they undergo *calcification*. As we shall see later, most of us are carrying healed tubercles somewhere in our bodies.

Whenever tubercles are present in an organ we say that tuberculosis of that organ exists. Every organ in the body may be attacked by tuberculosis, but in some it is much more frequent than in others. *In adults the lungs are the organs most often affected; while in children tuberculosis of the lymph glands*, (Fig. 71) *bones, joints, intestines*, and *the brain and its coverings* is more common.

Transmission.—The ways in which tubercle bacilli are cast off from the body depend, naturally, on what organs are affected. In tuberculosis of the lungs the *sputum* is the chief source of infection. In tuberculosis of the kidneys and bladder, the bacilli may be present in the *urine* in large numbers. The germs are present in the feces in tuberculosis of the intestine, and in the pus from tuberculous abscesses.

The excretions of the tuberculous patient are the means by which the disease is spread, and the most important of these is the sputum, which is the source of danger in a great majority of cases. The sputum of consumptives may contain an enormous number of bacilli. It has been proved that a single patient who is raising a considerable amount of sputum may throw off in twenty-four hours 500,000,000 to 3,000,000,000 bacilli. A coughing or sneezing consumptive throws out a spray of sputum containing tubercle bacilli, and this may be breathed in by another person.

The bacilli enter the body through either the respiratory or the intestinal tract. Frequently, perhaps always, tuberculosis of the lungs is caused by bacilli which first get into the stomach or intestines, and then are carried by the lymphatics to the lungs, where they lodge and find conditions favorable for growth. Tubercle bacilli may also be inhaled in dust. If sputum is allowed to dry in open sputum cups or on handkerchiefs, floors, or bedclothing, the germs, which can remain alive for some time under these conditions, will be blown off by air currents and carried around as particles of dust. There is, however, less danger that this dust will be inhaled than that children will get it on their hands.

Much of the tuberculosis in children comes in through the mouth. A careless consumptive contaminates the floor or furniture with sputum, or expectorates into the street. Children, creeping on the floor, playing around the room or in the street, will get the bacilli on their hands and so into their mouths. The hand-to-mouth transference of sputum probably accounts for many of the tuberculous infections of childhood. A single consumptive who continually expectorates when outdoors may be the means of infecting many people. As will be explained later, children may also be infected by drinking the milk from tuberculous cows.

Food may be contaminated by handling it with fingers soiled with sputum, or it may be infected by flies which have crawled over tuberculous sputum. The common drinking cup or imperfectly washed spoon or fork may also carry the germs.

There is a difference of opinion as to whether infection occurs more often by inhaling infected droplets, or

by taking in the bacilli through the mouth; but which theory is correct makes no practical difference. The great majority of cases contract the disease through *contact, direct or indirect, with a patient, by means of sputum in some form or other.* We already have sufficient knowledge to guide our preventive measures successfully.

Diagnosis.—The diagnosis of tuberculosis in any part of the body is made, whenever possible, by examining the appropriate excretion—sputum, urine, etc.—and actually finding the bacilli with the microscope. Smears of the material are made on glass slides and stained by the Ziehl-Neelsen method to see if acid-fast bacilli are present. It is unsatisfactory to try to cultivate the bacilli, as is done in case of most other bacteria, because tubercle bacilli grow slowly and with difficulty in the laboratory. It is frequently necessary to make many examinations before the bacilli are finally found; therefore, *in suspicious cases one negative report is insufficient.*

When only a few tubercle bacilli are present in sputum, urine, pus, or other material, it may be impossible to find them with the microscope, and often the only method of discovering them is to inject a guinea pig with the material (Fig. 19). If this contains tubercle bacilli, the animal will die from tuberculosis in from four to six weeks, and the bacilli will then be found in large numbers. In the case of urine, the *sediment* is usually collected for staining or injection. In urine, acid-fast bacilli other than tubercle bacilli are sometimes found in stained smears. These will not cause tuberculosis. In cases of doubt, differentiation may be made by inoculation of the material into guinea pigs.

Diagnosis of tuberculosis of various organs may also be made by means of the x-rays. Caseous masses, cavities, and calcified tubercles give distinctive appearances which can be recognized by those trained in x-ray diagnosis (Fig. 71).

Tuberculous Infection and the Disease Tuberculosis. Tubercle bacilli may remain alive in the body for many years without giving symptoms or doing any harm. A considerable proportion of adults have been at some time slightly infected with the tubercle bacillus, as signs of it are found in the lungs in many autopsies on persons who never had any symptoms of tuberculosis and have died of other diseases. Further proofs of a preceding tuberculous infection are a positive tuberculin reaction (Fig. 72) as will be explained later, and, if the process has affected the lungs, characteristic shadows on the x-ray plate.

These signs mean that at some time tubercle bacilli have entered the body and grown there to a limited extent, although the defenses of the body have been strong enough to hold them in check. The bacilli are usually contained in the lymph glands along the trachea and bronchi. The glands become surrounded by thick coverings of connective tissue, as was mentioned above in speaking of the healing of tubercles. This connective tissue keeps the bacilli from getting out. In many people these glands are a storehouse for the tubercle bacilli, but the organisms never go any farther.

If at some later time the bacilli begin to multiply and are carried from the glands to other organs, as the lungs, where they set up an inflammation and produce sufficient poisons to cause symptoms, fever and loss of

weight, the disease tuberculosis is present. A large proportion of people over forty years of age have had a *tuberculous infection*, but only a comparatively few develop *the disease tuberculosis.* It is of the utmost importance to understand these facts because they explain much in regard to the disease.

Childhood Infection.—Infection often occurs during the first fourteen years of life. *Infection acquired during childhood*, however, *may not cause the disease until years later*, the bacilli remaining alive in the lymph glands during all this time. *Children are very easily infected with tubercle bacilli.* In fact, if a child has been exposed to the disease in the family through association with a tuberculous patient, it may be assumed that he is infected. In the infant, tuberculous infection is very liable to take the form of a generalized fatal infection. Adults, unless they have acquired the immunity that results from a slight, healed infection, may also acquire tuberculosis in the same severe form in which it occurs in infants. On the other hand, adults who have at one time had a slight infection and completely recovered from it, may have resistance even to marked and long-continued opportunities for infection. There is small danger to adults from chance contact with a consumptive.

The probability is that many cases of tuberculosis in adults come not from a recent infection, but from a *breaking down of the resistance of the body, which allows a childhood infection to start up.* The bacilli, which have been living quietly in the lymph glands, escape from them into a more favorable tissue, take on renewed energy, begin to multiply, and thus cause active tuberculosis.

The discovery that *many cases of tuberculosis in adults have their starting point in an infection during childhood* has given an entirely different viewpoint and also a hopeful method of fighting tuberculosis; that is, the *prevention of infection in childhood*, and the *special care of children who have been exposed to the disease.*

Tuberculosis, a Family Disease.—Tuberculosis is a family disease; that is, it "runs in families," occurring in each generation. The reason for this is that the child is heavily infected in the home by tuberculous parents or relatives. Opportunities for the transfer of tubercle bacilli are numberless. The child plays on the floor and soils its hands with dust and dirt containing the bacilli. A consumptive mother cares for the child and prepares its food with hands contaminated with sputum. The infection thus received in early life may not break out into active tuberculosis until the child is grown up and has children of his own. They are then infected in the same way, and thus the story is repeated.

Allergy in Tuberculosis.—It has been pointed out in a previous chapter that the presence of foreign proteins, including bacterial proteins, within the blood or tissues of the body often results in a condition of hypersensitivity or hyper-reactivity toward that protein. The patient is said to be in an *allergic condition* with regard to that particular antigen. Sometimes the allergic condition manifests itself as an itching or local inflammatory reaction when the protein gains access to the underlying cells of the mucous membranes or of the skin. It was pointed out that by artificially injecting or scratching a small amount of the protein in question into the skin of an allergic person, this

peculiar reaction can be called forth locally at will, showing the patient's allergic condition.

The Tuberculin Test.—The skin manifestation is particularly easy to demonstrate when a patient has had the protein of tubercle bacilli in his body. Tuberculosis infection, even though past and long since healed, and of which the individual may never have been conscious, still leaves him in an allergic condition toward tubercle bacillus protein. By scratching into the skin of the majority of adults, a few dead and broken up tubercle bacilli, a red, inflamed, itching wheal appears after a short interval (Fig. 72). It soon disappears and the test is an entirely harmless experiment. The reaction is called a *tuberculin reaction* and the dead and disintegrated tubercle bacilli, or their extracts are called *tuberculin.*

Tuberculins of various types were first developed by Koch, who thought he had devised a sort of vaccine against the disease and had great hopes of using tuberculin for the cure of tuberculosis. It has since been found, however, that tuberculin alone will not cure nor prevent the disease. In fact, if too much of it is introduced into the body of a person allergic to the protein, a very severe, generalized, allergic reaction may occur, instead of merely a local one on the skin. If the patient has live tubercle bacilli in his tissues, the reaction may give the germs a fresh start, thus greatly injuring the patient. This will be discussed more fully in the following section.

The tuberculin test is, however, widely used to detect tuberculosis in children. As has been previously pointed out, a large proportion of adults have at some time in their life had a slight tuberculous infection

which, in the great majority of cases, has healed. These persons nevertheless remain allergic to tubercle bacilli and therefore all give a positive tuberculin reaction, so that by this method it is impossible to distinguish between adults who still have the active disease and those who have recovered. In children, however, a number are found who give negative reactions, while in those who give positive reactions, the disease is probably actually present in a more or less active form, since they may not be old enough to have completely recovered.

Methods of Performing the Tuberculin Test.—Tuberculin may be applied in a number of ways, all of which are designed to bring the tubercle bacillus protein into intimate contact with the body cells. Von Pirquet described the method of scratching the tuberculin into the skin—*scarification*—and when the test is done in this way it is often called the *von Pirquet* or *cutaneous test*.

Sometimes the tuberculin is dropped into the eye. This is called the *Calmette* or *intra-ocular* tuberculin test and, when positive, results in a temporary inflammation of the conjunctiva. It is used chiefly for the detection of tuberculosis in cattle, seldom in human beings.

Moro mixed tuberculin with vaseline and, in the form of a salve, rubbed it into the skin of the back or chest.

Tuberculin may also be injected *intradermally* (Fig. 65). This, called the Mantoux method from its originator, gives the most sensitive reaction, but when large numbers of individuals, as school children, are to be tested, it is less easy to carry out than the scarification method, and parents are less likely to give consent.

Fig. 72.—A positive cutaneous tuberculin reaction (von Pirquet). Child with incipient pulmonary tuberculosis; a + reaction. The control scarification is barely to be seen, and is midway between the tuberculin reactions. (Kolmer "Infection, Immunity and Biologic Therapy").

When tuberculin is given *subcutaneously* to a hypersensitive person or animal, it produces a *general reaction,* with a rise of temperature lasting 24 hours or longer. This method is used more often for cows than for human beings.

B. Leprae (Mycobacterium leprae).—Another important member of the acid-fast group is the bacillus of leprosy, which resembles the tubercle bacillus in appearance and staining reactions. It occurs in great numbers in the lesions of leprosy. The organism was first seen in 1872 by the Norwegian scientist Hansen, and was thus one of the earliest pathogenic bacteria to be discovered.

In olden times leprosy was a common disease. In the Middle Ages it was frequent in Europe, but it declined, owing to the rigid isolation of lepers. A, present, the disease is largely confined to India, Japant and other Asaiatic countries. About 1,200 cases were thought to exist in the United States in 1926.

CHAPTER XXII

THE PREVENTION OF TUBERCULOSIS

Immunity to tuberculosis—The relation of tuberculosis to social conditions—Methods of prevention—The childhood type of tuberculosis—Tuberculosis among nurses—Classification of tuberculosis cases—Care of excretions—The antituberculosis movement.

The prevention of tuberculosis is of immense importance to the human race. Indirectly, tuberculosis enters into many public health questions and activities and into social problems.

In this chapter we shall discuss the prevention of tuberculosis from a purely practical standpoint, merely as an introduction to the nurse's further study of the disease from the scientific, clinical, public-health, and social[1] standpoints. All effective methods of preventing and combatting the disease rest on a foundation of bacteriology and immunology, and they are continually broadening and changing as scientific research increases our knowledge.

Immunity to Tuberculosis.—Less is known about immunity to tuberculosis than to some other diseases. It is apparently a more complex biological process than immunity to diphtheria, since the tubercle bacillus, unlike the diphtheria bacillus, does not secrete a strong soluble toxin which can be neutralized by an antitoxin. It probably produces an endotoxin.

[1] For a discussion from the two latter standpionts, see Chapter VII of Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

As far as we know at present, immunity to tuberculosis cannot be produced by inoculation of the products of the organism. As yet, no investigator has succeeded in making a vaccine or serum for the prevention and cure of the disease, which is powerful and absolutely safe.

We have already emphasized that immunity, or rather, resistance to tuberculosis is attained *naturally* by recovery from mild, symptomless infections caused by small doses of *living* bacilli picked up in the course of ordinary life. As a result of the first infection, the cells of the body become *sensitized* or *allergic* to the organisms. The next time infection occurs, the defenses of the body are mobilized more quickly to combat the bacilli. Most people, then, while growing up, deal successfully with repeated small doses of the organisms. They gradually become infected, but as their resistance keeps pace with their infection, they do not develop the disease. Nevertheless, immunity to tuberculosis is not strong enough to overcome a large amount of infection. When immunity fails in an infected individual, symptoms of the disease make their appearance.

When an infection becomes active, something has happened to break down the defenses of the body and allowed the bacilli to get a start. A person's resistance to tuberculosis is not fixed, but is always changing throughout his lifetime. Sometimes it is high, sometimes low. It is kept at a high level by everything which leads to a normal life—good food, fresh air, sufficient rest and recreation, in fact, everything that keeps one in good condition. It is diminished by anything which decreases bodily vigor. Among these

influences are: other infections, such as measles, whooping cough, and influenza; too frequent child-bearing; overstrain and fatigue; poor living conditions of all kinds; alcoholism; and malnutrition.

The Relation of Tuberculosis to Social Conditions.—Tuberculosis is *closely connected with social conditions* in a community. It is much more frequent among the poor than among the well-to-do, and its prevalence is related to poverty, ignorance, overcrowding, overwork, poor nutrition, alcoholism, and infectious diseases. Low standards of living mean lack of isolation, of rest, sunlight, fresh air, and cleanliness; lack of medical and nursing care; insufficient food; and, in fact, all the conditions that tend to spread the infection and prevent the patient's recovery. The death rate from tuberculosis in any community indicates clearly what are the social conditions. If they are bad, the death rate from tuberculosis is high; while if the population is in good circumstances, well fed, and not overcrowded or overworked, the death rate from tuberculosis is low.

There are two main ways of preventing active tuberculosis. The first is to prevent the heavy infection of children; we shall discuss this later. The second is to keep the resistance of infected persons at such a high level that the bacilli present in the body cannot spread and multiply, and thus produce the disease. This is just as truly prevention of tuberculosis as is the protection of children. We have already mentioned some of the influences which may cause an infected person to break down with the disease. Some of the measures which will help to prevent such a breakdown are: diminishing the number of preventable

infections, particularly those of the respiratory tract; better care during convalescence from various diseases, and during childbearing; avoiding overfatigue and overstrain, both physical and mental. All efforts which improve the conditions under which people live and work have their influence in diminishing tuberculosis.

The discovery that childhood is the time when many adult cases of tuberculosis have received their infection shows us where to concentrate our efforts for preventing the disease with the greatest hope of success. The feature of tuberculosis prevention at the present time is the increasing emphasis placed on the child and the adolescent. *The children who are today being exposed to the disease will form a large proportion of the consumptives fifteen or twenty years from now.* Real protection of children in a family in which there is a case of tuberculosis is impossible. There will be infection in spite of all attempts to prevent it. Either the patient should go to an institution, or the children should live elsewhere. *The welfare of the children must be the first consideration,* since it is only by protecting them that the ravages of the disease in the family can be stopped in the present generation.

The Childhood Type of Tuberculosis.—The most frequent form of tuberculosis in childhood (from five to twelve years) is infection of the lymph glands of the neck and chest. The symptoms of tuberculosis in children are failure to gain weight, loss of energy and appetite, and increase in the afternoon temperature from ½ to 1 degree, and occasional attacks of fever, called "colds." More important than the symptoms, however, are a positive tuberculin reaction, a characteristic *x*-ray picture of the chest (Fig. 69), and a history of expo-

sure to tuberculosis. *All children who are delicate, easily fatigued, and not gaining weight should have a thorough medical examination. Every child who has been exposed to tuberculosis in the home should be under medical supervision for many years.* Childhood is the time of life when the disease can be most readily overcome, if it is diagnosed and proper treatment started. The hope for the final victory over tuberculosis lies to a great extent in the prevention of the heavy infection of children, and such good care of those who have been infected that the disease will never develop.

Tuberculosis among Nurses.—Evidence has accumulated to prove that both in the United States and in other countries, tuberculosis is considerably more frequent among nurses than among women of the same ages in other occupations. This may be the result of a breakdown of resistance in an individual who has been heavily infected in childhood, or the infection may be acquired from a patient during the training period or later. Systematically repeated tuberculin tests on groups of student nurses have shown that many infections are acquired during the period of training, presumably from patients.

This very serious situation has only recently been brought to light. What are the remedies for it? First the physical examination *before* acceptance in the school should include an *intradermal tuberculin test* and a *chest plate.* Such a study would result in diverting into less arduous occupations heavily infected girls who would be unusually liable to develop the disease. It would also allow them to begin a modified way of living long before the disease would have been detected otherwise, and at a very favorable period.

Second, the tuberculin test should be repeated every six months on nurses who have previously been negative, and an x-ray film of the chest made at the same intervals on all positive reactors.

Third, better supervision should be maintained over the general health of the students and the amount of work required be kept within reasonable limits. Overwork and unnecessary hardships may break down even a normal girl's resistance.

Fourth, the nursing of actual and possible tuberculous cases should be performed with a rigorous communicable-disease technic. The nursing of tuberculous, like that of any other contagious patients, is a professional hazard which must be assumed, but it can be undertaken intelligently and to a large extent guarded against. The evidence appears to show that there is more carelessness in regard to tuberculosis than in the case of other contagious diseases.

Classification of Tuberculosis Cases.—Cases of tuberculosis are classified as "open" or "closed." An open case is one who is casting off bacilli in the sputum or other excretion; a closed case is one who is not throwing off the bacilli, and is, therefore, not a danger to others. An open case may heal and become closed; a closed case may start up again and become open.

Care of Excretions.—As with any other infectious disease, the proper *care of the excretions* by which the disease is spread must be rigidly carried out. Every consumptive must be taught to live so that he will not be a danger to others. He need not be isolated like a case of acute infectious disease, if he is careful and cleanly; but he must take proper precautions to protect

others. He should use paper sputum cups and gauze or paper handkerchiefs. When away from home he should carry a pocket sputum flask. He should have a separate set of dishes, which should be boiled after use. He should sleep alone. He should take special pains not to soil his hands with sputum, and he should avoid contact with children.

Every tuberculous patient must be trained to avoid exposing others, and he must also be taught how to live hygienically so as to help along his own recovery. This teaching is the most important function of the sanatorium, and it can also be carried out successfully at home. The training, care, and encouragement of the patient in his own home is largely given over to the nurse, and forms one of the most important and hopeful branches of public health nursing.

The Antituberculosis Movement.—All civilized countries are today carrying on a **public health campaign against tuberculosis.** Here we can mention only the chief agencies that are being used in the United States.

1. The first is the *tuberculosis clinic,* which examines patients, makes the diagnosis, treats those patients who must remain in their own homes, and supervises patients who have returned from sanatoria. Attached to the clinic are **public health nurses,** who visit all patients under the care of the clinic, make arrangements for treatment at home, and instruct the patients and their families as to the necessary precautions. Tuberculosis nursing was one of the earliest forms of public health nursing to be developed.

2. The *sanatorium* is for the early and more hopeful cases of tuberculosis. Its most important function is

training the patients, teaching them the precautions they must take to avoid infecting others, and also right habits of living, so that they may keep the gains they make under treatment.

3. The *tuberculosis hospital* is for the care of advanced cases. It is of great value in the isolation of these patients who are the greatest sources of infection on

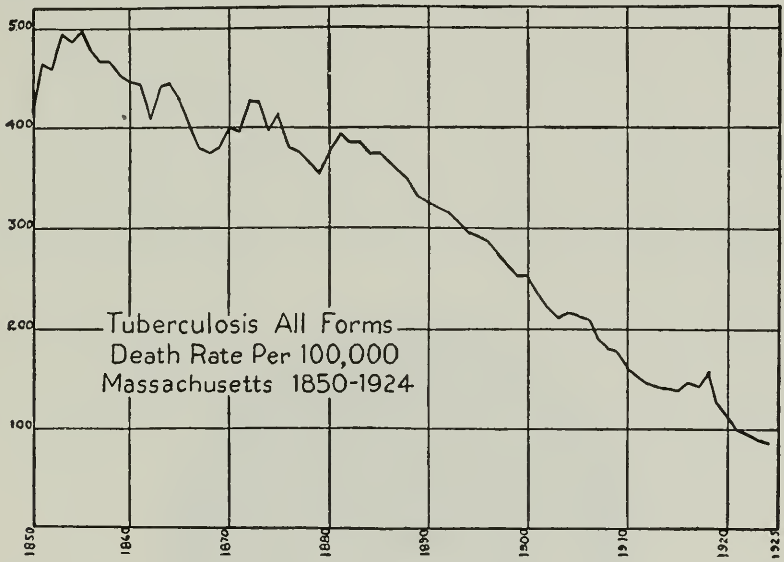


Fig. 73.—Chart showing the decline in the death rate from tuberculosis. (From Rosenau "Preventive Medicine and Hygiene," D. Appleton and Company, Publishers.)

account of the large amount of sputum which they excrete.

4. The *preventorium* is for children who have been exposed to the disease and are undernourished, but have not yet developed active symptoms. Its object is to prevent the development of tuberculosis by building up the children's resistance by means of food, fresh air, rest, and the correction of physical defects.

The outlook for the final victory over tuberculosis is encouraging. In the United States there has been a

marked and steady decline in the death rate during the last hundred years, and this is still going on (Fig. 73). Between 1900 and 1920 the death rate was almost cut in half. Many causes have contributed to the decrease in tuberculosis, some directly, some indirectly. The antituberculosis campaign which has been carried on continuously in this country for the last forty years, has been of immense importance; but even more valuable has been the change which has come over the mode of life of the American people in the last generation—more hygienic personal habits, more outdoor life and recreation, a more rational diet and consequently better nutrition, more sensible ways of bringing up children, and a general interest in matters of health. There has also been an improvement in social and industrial conditions, and the general average of health, physical comfort, and wholesome interests has increased. All these various influences tend to prevent breakdowns from tuberculosis.

CHAPTER XXIII

THE SPIROCHETES

Characteristics—Species—*Spironema vincentes*—*Spironema recurrentis*—*Spirochaeta pallida:* characteristics—The course of syphilis—Congenital syphilis—Diagnosis of syphilis: dark field; Wassermann and Kahn reactions—Arsenicals in syphilis—Importance of prompt and thorough treatment—Treatment by induced fever.

THERE is a fairly large and comparatively little known group of organisms which bear the general name of *Spirochete*. These organisms are wavy or

Fig. 74.—The Spirochaeta pallida enlarged 1000 times. Dark field preparation made from chancre. The white blotches in the background are secretions from the chancre. (Todd and Sanford, "Clinical Diagnosis by Laboratory Methods.")

are spirally constructed. Some of the harmless species are much larger than bacteria. The spirochetes are regarded by many workers as being more like single-

celled animals than plants. It is generally agreed that they are probably not true bacteria. They appear to constitute an independent group between the lowest plants, the bacteria, and the protozoa, the lowest animals.

Spirochetes of various species live free in the outside world. Only a few species are harmful. Harmless spirochetes are found in some drinking water supplies, oysters, the mouth, india ink, etc.

Some of the spirochetes, especially the species causing syphilis, are not easily stained by ordinary methods. To demonstrate them, a special apparatus, called a "*dark field*," is commonly used. The directions for operating and the principles on which it is based are too complicated to discuss here, but may be found in textbooks of physics, or of medical bacteriology. When organisms or particles are seen in the dark field they appear brightly illuminated against a dark background, like dust particles in a beam of sunlight shining into a dark room. (Fig. 74).

Species.—There are several species of spirochete of importance to man. The most important are listed below:—

Name	Disease Caused
Spironema vincenti	*Vincent's angina*
Spironema recurrentis	*Rat-bite (or relapsing) fever*
Leptospira icteroides (probably identical with *Leptospira icterohemorrhagiae* which causes a form of hemorrhagic jaundice (Weil's disease).	
Treponema pallidum	*Syphilis*

Spironema Vincenti.—This organism is anaërobic and is difficult to cultivate in the laboratory. Vincent's angina is an infectious disease which usually attacks

the gums and tissues of the mouth, causing a gangrenous ulceration with an offensive odor. The spirochetes are found in enormous numbers in the ulcers, always associated with a long, thin, spindle- or cigar-shaped bacillus (Fig. 75). Both stain well with ordinary stains and the diagnosis may be made by staining material from the ulcers and examining it microscopically.

Fig. 75.—Throat smear, Vincent's angina, showing the spirochetes, which stain lightly, and the cigar-shaped bacilli which always accompany them. The darkly stained masses at the left are nuclei of leukocytes. (From Hiss, Zinsser and Russell, "Text-Book of Bacteriology," D. Appleton & Co., Publishers.)

The disease is transmitted by drinking glasses, eating utensils, kissing, and articles which come from an infected mouth. Vigorous disinfection of the mouth usually cures the infection. Arsphenamine, the same drug used for the treatment of syphilis, is also said to give prompt relief in many cases.

Spironema Recurrentis.—Relapsing fever is of interest chiefly to those in the tropics. It is seldom seen in the temperate parts of the United States. The

spirochete (Fig. 76) can be transmitted normally only by the bite of rats and certain insects. It gets its name from the frequent and regular recurrences of the fever in the patient. It presents no nursing problems.

The Spirochæta Pallida.—This organism, properly called the *Treponema pallidum*, is the cause of syphilis.

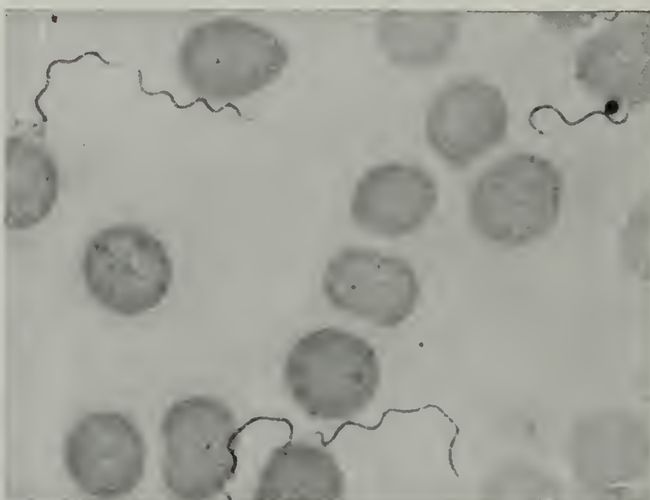


Fig. 76.—The spirochete of relapsing fever, seen in a blood smear. (From preparation furnished by Dr. G. N. Calkins.) (From Hiss, Zinsser and Russell, "Text-Book of Bacteriology" D. Appleton & Co., Publishers.)

It was discovered by Schaudinn, a German scientist, in 1905.

Characteristics.—This spirochete is a slender, delicate, corkscrew-like organism. (Fig. 74.) When examined in fresh preparations from syphilitic sores, it is seen to be in active movement, gliding backward and forward and rolling from side to side. It has been described as "an animated corkscrew." It is spoken of as "pallida" because of its pale appearance when viewed with the microscope. It is not stained with

ordinary dyes, but requires special and complicated methods for its demonstration in smears. It is most easily demonstrated in the living, unstained condition by examining a drop of secretion from a syphilitic sore with a dark-field apparatus.

Not much is known about the life history of the spirochete. It grows with great difficulty in the test-tube, only under special conditions and in the absence of oxygen. It was first cultivated by Noguchi at the Rockefeller Institute. Growth is slow, as the colonies become visible to the naked eye only after two weeks' time.

Fig. 77.—Chancre of the lip. (Keidel.)

The organism dies quickly outside the body, as it is very sensitive to drying and to disinfectants. Soap is quickly fatal to the spirochete. Any material that has dried will not carry the disease, but objects recently soiled or still moist with secretions containing the spirochete are possible sources of infection. The limit of life of the germs on ordinary objects is not more than six or eight hours. The disease is occasionally transmitted by such articles as towels, glasses, spoons, and pipes, but the great majority of cases are acquired by direct contact with the infected person.

The Course of Syphilis.—The Spirochaeta pallida gains entrance to the body through breaks in the skin

or mucous membranes, most often on the genital organs, occasionally on the lips, and causes an ulcer, called the *primary sore* or *chancre* (pronounced shank′er). After a time this usually heals without treatment, but this does not mean the disease is cured. It simply means that the germs have left this particular spot and invaded the body. Within a short time, varying probably from a few hours to several weeks after infection, the spirochetes get into the blood and are carried to every organ in the body. As a general rule, but not always, following the general invasion of the body, possibly as long as several months after the appearance of the chancre, a rash appears, there are sores in the mouth and on the genitalia, sore throat, slight fever, and headache. This is called the *secondary stage*. Syphilis in this stage is an *acute infectious disease*. The ulcers and sores swarm with spirochetes, and the disease may be spread at this stage by the patient himself or by things still moist with his secretions.

After a number of weeks, these early symptoms also disappear without treatment; but still the disease is not cured; it enters on the *chronic stage*, called the *third or tertiary stage*. *Like the tubercle bacillus, the Spirochaeta pallida may remain alive in the body for many years without causing any symptoms*. It may attack almost any organ in the body. In the later stages of the disease there are long periods during which symptoms are absent, and the patient may believe himself cured. The disease then breaks out again. The fact that such a long time elapses between the original infection and the late manifestations of syphilis, caused many of the symptoms and lesions of

the later stages to be regarded as entirely different diseases, and to be named as such until their syphilitic

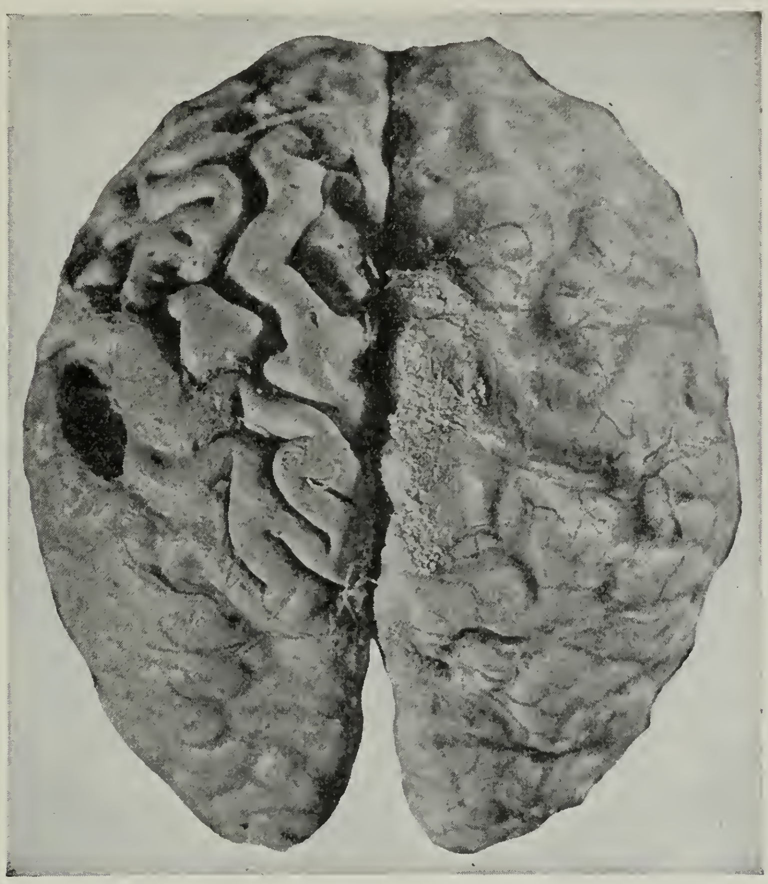


Fig. 78.—The brain in general paresis, viewed from above. Over the right hemisphere and the posterior part of the left, the chronically inflamed pia mater obscures the convolutions. It has been stripped off from the anterior part of the left hemisphere, revealing the convolutions which are shrunken because of loss of nerve tissue. The disease manifests itself by a characteristic dementia, and is finally fatal unless the most modern treatment is given. (Courtesy of Dr. L. H. Cornwall. From Wechsler "Clinical Neurology.")

nature was fully understood, by actually demonstrating the spirochetes in the tissues.

The late symptoms of syphilis depend on the organ which is attacked by the spirochetes. The most fre-

quent, serious, and disabling results of syphilitic infection are *diseases of the heart, arteries, and nervous system.* These are frequent causes of early death in syphilitics.

Fig. 79.—A cross section of the spinal cord in tabes. The anterior part of the cord is toward the bottom of the picture. The outlines of the gray and white matter are easily identified. The white matter (which is stained dark in this section) represents a cross section of nerve fibers. In the center of the posterior part of the cord are areas in which the nerve fibers have degenerated through the action of the Spirochaeta pallida. The fibers in the affected area normally carry to the brain the impulses which give the sensations of touch, pain, and sense-of-position. The involvement of these fibers causes the characteristic signs and symptoms of tabes. Have you ever seen a tabetic walk? (Courtesy of Dr. L. H. Cornwall. From Wechsler "Clinical Neurology.")

The spirochetes lodge particularly in the walls of the arteries, causing a chronic inflammation and

destroying tissue. Consequently, the vessel walls may bulge, causing sac-like dilatations called *aneurysms*. These not infrequently burst and the patient may die of the hemorrhage. Syphilis is the cause of *aneurysm of the aorta*, of many cases of *disease of the aortic valves*, and it is frequently responsible for *arteriosclerosis and cerebral hemorrhage in comparatively young persons.*

Unless treatment is given early, the spirochetes lodge also in the central nervous system (brain and spinal cord), where they cause a chronic inflammation and destroy the nerve tissue. These lesions result in *paresis*, (general paralysis, or dementia paralytica),

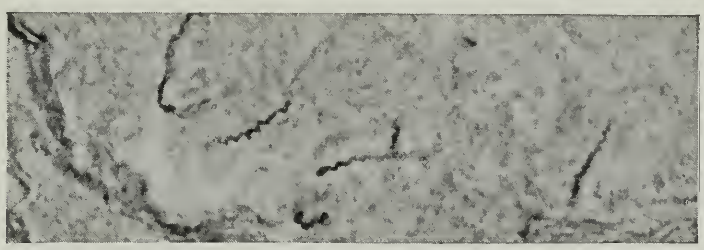


Fig. 80.—Spirochaeta pallida in the liver of a congenitally syphilitic infant. The background is liver tissue. (From Hiss, Zinsser and Russell "Text-Book of Bacteriology" D. Appleton & Co., Publishers.)

and *locomotor ataxia*, or tabes (Fig. 79). About one-fifth of the male patients in hospitals for mental diseases are paretics. In paresis, spirochetes are present in the tissues of the brain; in tabes, in the spinal cord.

After the early symptoms have passed, the syphilitic is no longer infectious in the ordinary relations of life, although small numbers of spirochetes remain alive in the body. This is an important point for nurses to remember, as they are often unnecessarily afraid of patients in the later stages of the disease.

Congenital Syphilis.—A woman may transmit syphilis to her child if she has the disease at the time of

conception or acquires it during pregnancy. The spirochetes pass from the mother through the placenta into the blood of the fetus, as they are one of the few organisms which can pass the barrier of the placenta. The baby is thus infected before birth and comes into the world with living spirochetes in its body (Fig. 80). This is called congenital syphilis (congenital meaning present at birth).

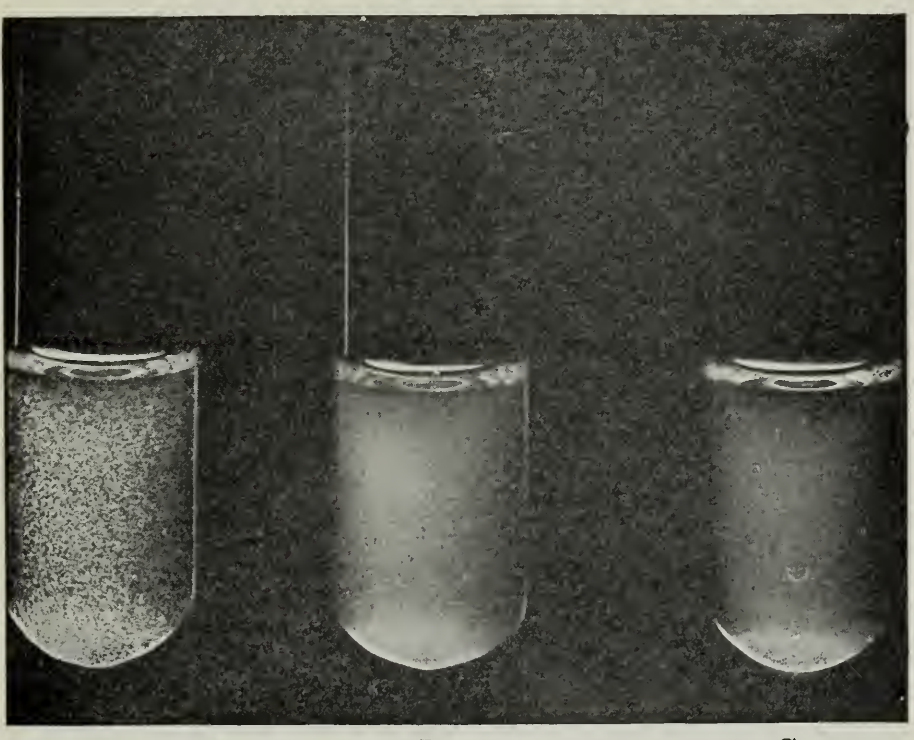
Many pregnancies in syphilitic women end in *miscarriages* or *stillbirths.* Syphilis is the most frequent cause of the death of the fetus during pregnancy. The child may be born alive showing signs of syphilis or these may develop later. *Syphilis is a cause of much infant mortality.* Many cases of prematurity and "marasmus" are really due to syphilis. As in the case of adults, the spirochetes may remain alive in the child's body for a number of years without giving symptoms and then become active. After infancy, the most serious consequences of congenital syphilis are stunting of growth, diseases of the eye, deafness, epilepsy, and feeblemindedness.

Syphilitic babies with a rash and sores around the mouth and anus are infectious. There is practically no danger, however, from older congenitally syphilitic children.

About 5 per cent of patients in children's wards are said to have congenital syphilis.

Diagnosis of Syphilis.—The most satisfactory method of diagnosis in the first stage of the disease is the demonstration of the spirochetes with the dark-field apparatus in fresh, unstained material obtained from the chancre, or sores in the mouth or elsewhere (Fig. 74). These contain the organisms in great numbers. The Wasser-

mann and Kahn reactions become positive only in the second or third week after the appearance of the chancre. They cannot, as a rule, therefore, be used for diagnosis in the very earliest stages, but later they are most



A B C

Fig. 81.—The Kahn reaction. *A*, strongly positive. Definitely visible particles are suspended in the transparent medium. *B*, a weaker reaction. Fine particles are suspended in a somewhat turbid medium. *C*, negative reaction. The medium is transparent and free from particles. (From Kahn, "The Kahn Test," Williams and Wilkins Co., Publishers.)

reliable tests. It is very important to make the diagnosis before these reactions become positive, in order that treatment may be started at once.

Wassermann and Kahn Reactions.—Serum of the patient is required for these reactions. Blood for the

test is drawn from a vein at the bend of the elbow, at least 10 cc. being usually required (Fig. 110). The mechanism of the Wassermann test has been discussed in Chapter VII, to which the student should now refer again.

A strongly positive test is usually designated by the symbol four plus (++++); weaker reactions as three plus (+++), two plus (++), one plus (+), and plus-minus or doubtful (±).

Another test for syphilis, developed in 1921, is called the Kahn test (Fig. 81). This is simpler and quicker than the Wassermann test and is thought by many investigators to be more reliable. It may eventually replace the Wassermann test. It has been adopted by the United States Navy and some health departments. The test depends on the fact that when a concentrated alcoholic antigen, similar to that used in the Wassermann test, is mixed in certain proportions and in a certain way, with the serum of a syphilitic patient, very fine particles are formed which cloud the mixture and may eventually clump together into flakes or *flocs* and settle to the bottom of the tube. Because of this floc formation, the Kahn test is classed as a flocculation or *precipitation* test.

The Wassermann and Kahn reactions are two of the most valuable aids which we now possess for the diagnosis of syphilis. The tests differentiate syphilis from other conditions which resemble it. A patient in the first (chancre) stage of syphilis may give a negative Wassermann or Kahn test because in the very early period of syphilis, as in most diseases, not enough amboceptor *i. e.*, antibody caused by the stimulation of the organisms, has appeared to give a positive reaction. The

test becomes positive sometimes ten days or two weeks after the appearance of the chancre. A patient's blood serum may give a positive Kahn or Wassermann test many years after infection, and it thus makes possible a diagnosis of the disease in persons who have had no visible signs for years. The reactions may become negative after treatment. After treatment is begun, the reactions are found to be weaker, and become progressively weaker as the treatment is continued. This is a favorable sign, and repeated tests are therefore made to find out how the treatment is progressing. Congenitally syphilitic children usually have a positive reaction.

If the brain or spinal cord is affected by syphilis, the Kahn or Wassermann reaction is usually given by the *cerebrospinal fluid.* The reactions are practically always positive in paresis and frequently positive in locomotor ataxia.

Arsenicals in Syphilis.—Arsenic has been found to be highly poisonous to the spirochaeta pallida. Several drugs containing arsenic are used in the treatment of syphilis, among them *arsphenamine, sulpharsphenamine, neoarsphenamine,* and *tryparsamide.* Although they are much safer than pure arsenic, much caution must be used in their administration. Solutions of them are injected into the vein at the elbow. The results of treatment in the early stages of the disease are remarkable. The spirochetes disappear, the sores around the genitalia and in the mouth heal very rapidly, and the Kahn and Wassermann reactions become negative.

The production of arsphenamine in 1910 by Paul Ehrlich (see Frontispiece) and his collaborators is one of the great medical advances of the twentieth century.

The discovery was of vast importance not only in relation to syphilis but in a still larger way, because it opened up a new field of treatment of various diseases by means of chemical substances prepared experimentally in the laboratory for the special purpose; *i. e.*, *chemotherapy*, the possibilities of which are as yet only dimly realized.

Importance of Prompt and Thorough Treatment.—Unless all the spirochetes in the body are reached by the arsenical drug, the disease is not cured. If the drug is discontinued, the disease will again make progress and the blood tests again become positive. Treatment must sometimes be continued for months or years in order to obtain a persistently negative test. Much depends on how soon after infection treatment is started. If the spirochetes are located in some deep, obscure, well protected lesion in the body, the arsenical may not reach them for a long time.

The chances of permanent cure diminish in proportion to the length of time which elapses between the time of infection and the beginning of treatment. It is of the utmost importance to get every syphilitic under treatment as early as possible, both for his own sake and that of the persons with whom he comes in contact.

Treatment by Induced Fever.—In the later stages of syphilis, arsenical treatment is often too slow or entirely ineffective. For a long time it had been observed that paretics who had contracted some severe febrile disease often appeared improved with respect to their syphilis after recovery from the fever. A treatment for paresis and other forms of syphilis was therefore devised, based on the intentional production of a febrile condition. One of the first of these methods was the infection of the

patient with malaria. This produced repeated febrile attacks, the high temperatures of the body probably killing the spirochetes. The malaria could then be eradicated by quinine treatment. The method was not entirely safe, but when properly controlled, was no more hazardous than some types of drugs. Other fever-producing organisms, such as the spirochetes of relapsing fever, have also been tried. More recently a method of inducing high fever by means of exposure to certain high frequency electrical oscillations has been discovered and has been found to give promising results in the treatment of brain syphilis.

CHAPTER XXIV

THE PUBLIC-HEALTH ASPECTS OF SYPHILIS AND GONORRHEA

Prevalence—Death rate—Syphilis as a family disease—The prevention of syphilis and gonorrhea: limitation of infection; early treatment; hospital and dispensary accommodations; treatment and prevention of congenital syphilis; educational, legal, and social methods.

Prevalence.—There are no exact statistics on the prevalence of syphilis and gonorrhea in the United States. The most accurate ideas which we have at present are based on examinations of different groups in the population. The frequency of the two diseases combined among young men of all classes is apparent from the figures for the recruits received in the army camps during the World War. From September to November, 1918, of 165,835 white men examined, 3.55 per cent were found to be infected, and of 40,094 colored men, 20.7 per cent. It is not probable that there has been much reduction in prevalence since that date.

Syphilis is much more wide-spread in the community than is generally supposed. Physicians who have studied the question most thoroughly consider it a safe estimate to say that from 8 to 10 per cent of the population of large cities have been infected with the disease. It has been estimated that there are between six and ten million syphilitics in this country. Syphilis and tuberculosis rank together as the greatest causes of

disability and death in the colored race. Recently a large number (over 7000) of the population in certain sections of the state of Mississippi were examined by means of the Wassermann test. Of the colored persons tested, about 17 per cent gave a positive reaction.

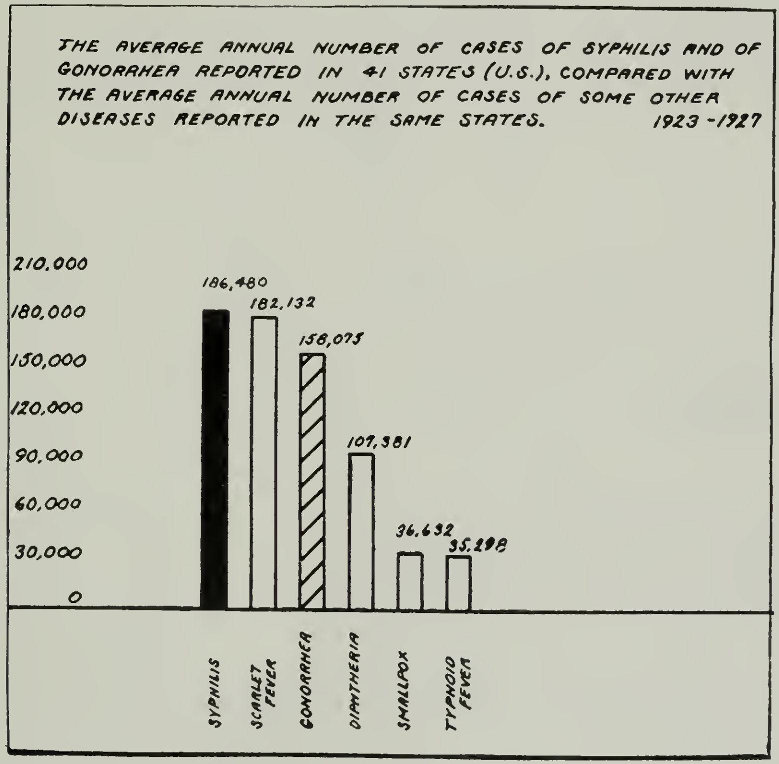


Fig. 82.—Courtesy Massachusetts Department of Public Health and U. S. Public Health Service.

Like other communicable diseases which are a menace to public health, syphilis and gonorrhea are *reportable to the health department.* Although this procedure is very incomplete, the relative frequency of reported cases of the two diseases in comparison with some other infections is seen in Fig. 82.

As for gonorrhea, it would be a hopeless task to try to determine the frequency of this disease among the

general population, as so many cases are mild and are treated with indifference.

Fig. 83.—Clinic in operation with clinician and nurse administering arsphenamine (salvarsan) for syphilis. (From "Two Years Fighting Venereal Diseases," Published by U.S.P.H.S.)

Death-rate.—The total number of deaths from syphilis is unknown because the disease rarely kills immediately, and most of the deaths for which it is

really responsible are reported as due to other diseases, chiefly those of the heart, arteries, and nervous system. Nevertheless, in 1929 there were reported in the United States 16,188 deaths from syphilis, locomotor ataxia, and paresis combined. Even this incomplete account ranks syphilis fourteenth among the causes of death, and if the true figures could be collected, syphilis would probably be classed among the most frequent causes of death, along with tuberculosis and pneumonia. Probably almost half of all syphilitics die from some of the late results of their infection.

Syphilis as a Family Disease.—Syphilis is a family disease quite as much as tuberculosis. If the husband has the disease, it is quite likely that the wife and children have also been infected. The effect of syphilis on the family is demonstrated in the study by H. C. and M. H. Solomon in Boston. At least one-fifth of the families of the patients examined were found to have one or more syphilitic members in addition to the original patient. In more than one-half of the marriages there had been either no children or miscarriages and syphilitic children. The members of the family usually have no idea that anything is wrong with them and consequently the disease is often overlooked until irreparable damage has been done.

If one person in a family is found to have syphilis, it is of the greatest importance to have the other members examined. By getting the infected members under treatment early the late results of the disease may be avoided.

The Prevention of Syphilis and Gonorrhea.—This is one of the most urgent public health questions. Syphilis and gonorrhea should be dealt with in the same way as are other communicable diseases. The immediate

problem is to *prevent the spread of the infection.* This is done by precautions taken by the patient and by making him noncontagious as soon as possible through treatment.

Unfortunately, persons in the most infectious stages of gonorrhea and syphilis are usually not incapacitated. They continue at their daily work, and hence are more liable to spread the disease than are persons who are confined to bed and thus partially isolated.

During the infectious period the patient should keep himself and the things which he uses away from others. This means a separate bed, separate eating utensils (for syphilitics), towels, wash cloths, etc., and sterilization of articles contaminated by the secretions, in the same way as in any infectious disease.

The syphilitic can be made noninfectious in the ordinary relations of social and business life in a short time by *treatment with arsphenamine.* Three to five injections will go far toward making the patient noninfectious, so that he will no longer be a danger except to those in the closest contact, although he must still continue to observe precautions. This is one of the most practical ways of diminishing syphilis. Most state, and many city, health departments now conduct clinics (Fig. 83) where treatment may be obtained free of charge. Many hospitals coöperate in the campaign.

Treatment begun early and continued faithfully tends to prevent the later symptoms, such as diseases of the heart, arteries, and nervous system. Syphilis is probably not incurable if treated early and thoroughly. Treatment begun at a later period will in many instances prevent the advance of the disease, although it is too late for a cure.

Finding as many of the infected persons as possible and getting them under treatment is a most important part of the program for the prevention of these diseases. A Wassermann or Kahn test should be made on every hospital, dispensary, and institutional patient, because unrecognized and late cases of syphilis are found in every large group of the general population.

Sufficient hospital and dispensary accommodations for the treatment of syphilis and gonorrhea are also necessary if the damage which these diseases do is to be diminished. Practically all hospitals refuse to take syphilis and gonorrhea in their early and curable stages, although they are perfectly willing to care for the complications and the late and incurable conditions. The clinic, as mentioned above, serves as a center for the diagnosis, treatment, and instruction of the patient and his family. It is also the starting point for coöperation with the medical and social agencies which are necessary for their restoration to health and their social reconstruction.

The *treatment and prevention of congenital syphilis* is one of the most important parts of the program against syphilis. It is a field in which vigorous preventive work will accomplish much. *Every pregnant woman should have a Wassermann or Kahn test,* and all those with a positive reaction should have thorough treatment. The earlier in pregnancy the mother comes under treatment, the better the chance that the child will escape injury.

The children of parents known to be syphilitic should be kept under medical observation, even though they show no signs or symptoms of the disease. The situation is similar to that of children in whose families

tuberculosis exists. In infancy congenital syphilis yields to treatment much more readily than in later childhood. If the disease were always well treated in infancy, the number of children showing the late and irreparable consequences of congenital syphilis would be much reduced.

The educational, legal, and social methods of attack[1] on syphilis and gonorrhea rank in importance with the medical, in combating these infections, but it is not within the province of this book to do more than mention them.

The educational campaign has been carried on vigorously during and since the late war by means of literature, notices, talks, lectures, and motion pictures. The aim has been to acquaint the public with the method of spread of these diseases and their results, using accurate, clear, and simple language, and presenting the subject in an unsensational and unsentimental way. The gradual sex teaching given to children and young people in the home and school would be included here.

The legal attack centers around breaking up prostitution as a business, and the protection of young girls and feebleminded women.

The social methods of combating syphilis and gonorrhea are as valuable for future results as are the medical methods in dealing with existing cases and preventing the spread of infection. These include home training in character and ideals, for poor home training is the greatest cause, except mental defect, of sex delinquen-

[1] For further discussion of the public-health and social aspects, see Chapter VIII of Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

cies among young people. Recreational, intellectual, and other interests which compete with those of sex, are important in raising the level of sex conduct, in both young people and adults. Public opinion and education are slowly acting forces, but they get at the root of the problem, and their gains are permanent. The immediate duty of medicine and nursing is to deal with the existing cases and to prevent the spread of infection; but at the same time they must be working for long-distance results.

CHAPTER XXV

ULTRAMICROSCOPIC VIRUSES

Ultramicroscopic viruses: nature and characteristics; diseases caused by—*Smallpox:* immunity—Vaccination: modern method; protection—Compulsory vaccination; vaccination of children—*Common colds:* importance; transmission; causative agent—*Influenza*—*Measles:* organism; transmission; complications; nursing; prevention; immunization—*Mumps*—*Chickenpox.*

Ultramicroscopic Viruses: Nature and Characteristics.—It has been indicated previously that there are disease-producing organisms or substances of such nature that they will pass through the fine clay filters (Fig. 23) which are able to hold back even the smallest visible bacteria. All these organisms or substances are grouped together under the general name of *filterable viruses.* We have learned, however, that the action of the clay or porcelain filter probably is not dependent entirely on the size of the pores in the clay, but depends on other conditions which at present are only partly understood. The term "filterable," therefore, conveys an erroneous idea, since by certain procedures bacteria can be made filterable or non-filterable at will. *Ultramicroscopic* is a better term, and is coming into general use. Ultramicroscopic means that the organisms are so small or of such nature that they cannot be made visible by even the most powerful microscopes. About 50 such viruses are known at the present time. They do not form a homogeneous group.

The fact that we cannot see these viruses has made their study extremely difficult. In addition, no one has been able to cultivate them on artificial media, as is done with bacteria. The viruses, to the best of our present knowledge, will grow only *as parasites in or on living cells*, preferably young cells. There are possibly one or two exceptions, although many investigators doubt even these. Some eminent authorities doubt even that viruses are living things. Probably none of the truly ultramicroscopic viruses has ever been cultivated on artificial media.

In this book no discussion of the actual viruses will be attempted, beyond stating some general properties common to all of them. They are, as a rule, readily inactivated by heat, most of them being susceptible to pasteurization (60 C. for 30 min.).

They do not, as a rule, remain active in body fluids, such as blood and sputum, for more than a few days at room temperature. There are, however, exceptions to this. If the body fluids are rapidly dried, preserved with glycerine, or frozen, some of the viruses remain active for many months, or even years.

In general, they appear to be somewhat more resistant to chemical disinfectants, such as phenol and bichloride of mercury, than most bacteria. In this, however, there are many exceptions and variations, as there are among bacteria.

Evidence has recently been brought to show that certain bacteria, at certain stages in their development, may undergo a change during which they resemble in many respects the ultrascopic viruses. According to this theory, the filtrable forms of the bacteria eventually return to the usual, normal forms, but are changed and

different from the type in which they had their origin, being able sometimes to ferment different substances and perhaps having different staining reactions. Although many bacteriologists remain skeptical of these filterable forms of bacteria, recent investigations make it clear that the life cycles of bacteria are much more complex than had previously been thought. This subject has already been touched on in the discussion of *dissociation.* It is possible that bacteriology is now standing on the threshold of discoveries which will revolutionize its theoretical foundations.

Diseases Attributed to Ultramicroscopic Viruses.—Since we cannot study the organisms directly, we study them through the diseases which they produce. Unfortunately, many diseases have been ascribed to ultramicroscopic viruses simply because no one has been able to discover the proper bacterium. It is possible that some of the diseases now classed as virus-diseases will later be shown to be caused by cultivable bacteria and vice versa.

The diseases caused in man by ultramicroscopic viruses are practically without exception *associated with cells of the body which are of ectodermal origin.* Nearly all of the virus diseases result in a *high grade* and *lifelong immunity.* There are, however, such notable exceptions to this as the common cold and dengue fever.

A considerable number of diseases of plants, animals and man are caused by ultramicroscopic viruses. Some of the common diseases produced in man by unknown or ultramicroscopic viruses are:

Measles
Mumps
Chickenpox

Smallpox
Yellow fever
Rocky Mountain spotted fever
Psittacosis
Infantile paralysis (*anterior poliomyelitis*)
Hydrophobia (rabies—"mad dog bite")
Epidemic or lethargic encephalitis (not African sleeping sickness)
Common colds
Influenza (?)

Only those printed in italics are discussed in this book.

Smallpox.—It is hard to realize today that smallpox was once the most prevalent and the most dreaded disease in the world. Before the days of vaccination ninety-five persons out of every hundred contracted it, and about one-fourth of those who took it died. Many of those who recovered were blinded or disfigured. It prevailed in China and other Eastern countries from remote antiquity, and has repeatedly swept over Europe in great epidemics. It is still frequent in uncivilized countries, especially those of the East, but owing to vaccination and the rigid enforcement of quarantine laws, it has decreased in most civilized countries.

In 1926 there were about 55,000 deaths in India due to smallpox. In some countries, as England, the disease has actually increased in recent years, owing to the activities of the antivaccinationists. In the United States in 1929 it caused 151 deaths.

Immunity to Smallpox.—It is a curious fact that although the cause of the disease is still unsettled, smallpox was the first disease to which immunity was obtained by artificial means. The method of protection was developed by practical experience, and

was carried on more or less successfully for hundreds of years before there was any knowledge of the scientific principles on which it is based. Even before the Christian Era, it was the custom in India and China to introduce under the skin of a healthy person a bit of pus from the eruption of a mild case of the disease, in the hope of producing a light attack. This procedure was called *inoculation.* Its disadvantages were that the disease so produced was infectious, and the attack sometimes proved to be severe or fatal. Nevertheless, it continued to be practised until vaccination took its place.

Vaccination.—The relationship between the mild disease cowpox and the dreaded scourge smallpox, has been pointed out in Chapter VIII. A person who has contracted cowpox from a cow is immune to smallpox. Jenner, an English physician, noticed this and it occurred to him that *if all people could be purposely inoculated with cowpox, then smallpox would no longer exist.* He experimented along these lines and in 1798 published the results of his experiments. As a result, smallpox today is on the decline. It has since been shown that cowpox is really a modified form of smallpox.

Jenner's methods were effective, but very crude. Vaccine virus is now produced scientifically and under conditions of surgical cleanliness (Figs. 30 and 31).

Modern Method of Vaccination.—The skin is washed with soap and water and then with alcohol, which is allowed to evaporate. The virus is expelled from the tube onto the skin, and with a sterile needle two punctures (Fig. 84) are made through the drop of virus. *Vaccination is a small surgical operation* and should be done only by a person who understands surgical cleanli-

ness. The wound may become infected like any other wound, and to this the complications of vaccination are due, and also the bad results cited by antivacinnationists.

After vaccination there is an incubation period of three or four days, during which there are no noticeable changes. Then, if the vaccination "takes," an eruption appears at the place of inoculation and goes through

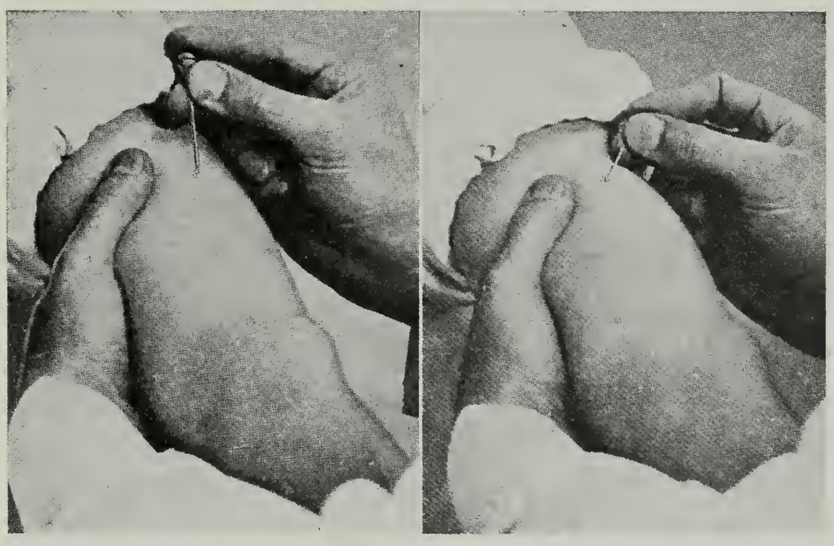


Fig. 84.—Vaccination by the puncture method. 1. Expelling vaccine virus from capillary tube on to cleansed skin. 2. Making punctures with needle point pressed through drop of virus. (Courtesy of Lederle Antitoxin Laboratories.)

certain characteristic stages, leaving a scar (Fig. 85). About the seventh day there is also a reaction on the part of the whole body, lasting several days, shown by fever, loss of appetite, general discomfort, and headache. During this time substances are being formed in the body which will protect against smallpox.

Protection Given by Vaccination.—This is complete for some time and then it gradually fades. It usually begins to disappear in two years and is almost com-

pletely gone in ten years. *Every child should be vaccinated between the ages of six months and two years and again when about twelve years old.* Two vaccinations usually protect for life, but adults should be revacci-

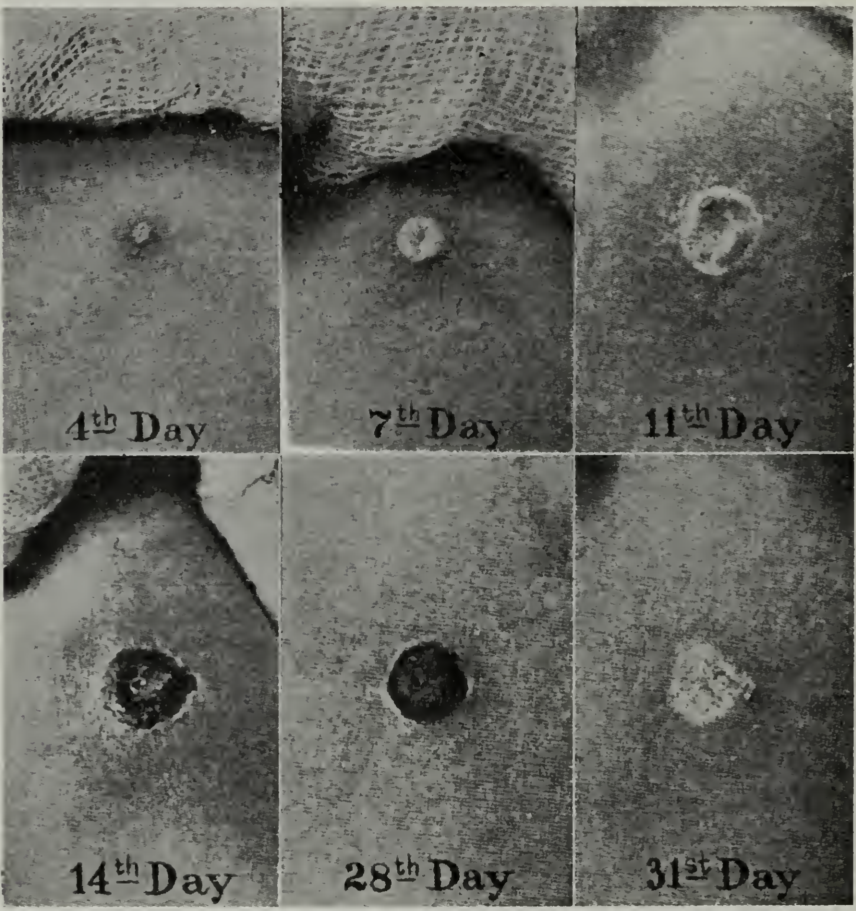


Fig. 85.—The course of the eruption in vaccination. (From Rosenau, "Preventive Medicine and Hygiene," D. Appleton & Company, Publishers.)

nated whenever the disease appears in the community, or when they are going to places where it is present. It is usually true that if revaccination takes, a person is susceptible to smallpox; but if it fails, he is not neces-

sarily immune, because the virus may have been weak or the vaccination improperly done.

Compulsory Vaccination.—*Smallpox can be absolutely prevented by the vaccination of a whole population.* There are many illustrations of this. The Phillippines, before the American occupation, had, in seven prov-

Fig. 86.—Children of one family who were brought to the Municipal Hospital of Philadelphia with the mother and father, who had smallpox. The child in the center had been considered too young to be vaccinated. The other children had been vaccinated a year before; they remained free from the disease, although for several weeks they lived in the wards of patients with smallpox. (From Welch and Schamberg, "Contagious Diseases," Lea & Febiger, Publishers.)

inces, more than 25,000 cases a year. In the year following vaccination, by the United States Army authorities, of all the inhabitants (over 8,000,000), there was not a single death from the disease. Some years later, the native health authorities became lax in regard to vaccination and a terrible epidemic

occurred. The carelessness of the health authorities cost in a short time the lives of over 50,000 people. Since then vaccination has been practised, and in 1926 there were only about six deaths from smallpox in the Philippines.

Vaccination of Children.—Persons are susceptible to smallpox at all ages; therefore early vaccination of children is advisable. Vaccination is required in some states before a child can be admitted to school. It is regrettable that many communities do not realize the necessity for this regulation. Much disfigurement, sickness, and death could be prevented by a rational view of vaccination on the part of those in control (Fig. 86). Ignorance, stupidity, distorted mental attitudes, false fears, and politics are responsible for the activities of the antivaccinationists and the power which they attain in otherwise enlightened communities.

Common Colds.—The true "common cold" usually starts with a "raw" or "scratchy" sensation in the posterior nares and pharynx. The nasal mucosa becomes acutely inflamed and a watery fluid is excreted copiously, accompanied by sneezing, watering of the eyes, headache, backache, and sometimes chills and fever. Unless complicated by some secondary infection, colds are usually of only three or four days duration and are not dangerous in themselves. They are, therefore, usually regarded lightly, but they are really a serious matter. The loss of time and efficiency on account of them mounts up to a tremendous total in a community. Still more important is the fact that the inflammation of the nose and throat which accompanies a cold prepares a favorable place for pneumococci, streptococci, diphtheria bacilli, and other organisms

to lodge and set up a more serious disease. A cold may thus be a forerunner of pneumonia, diphtheria, and other infections. Furthermore, if a person who is carrying streptococci, pneumococci, diphtheria bacilli, or other disease germs in his throat has a cold, he will distribute not only the organisms causing the cold but also any other germs which he happens to have on hand. The victim will catch both the cold and also the other infection.

Transmission.—Rather close contact between person and person is necessary for the transmission of a cold. The nasal discharge and saliva carry the organisms, whatever they may be, and the ways in which the infection is spread are many—for example, coughing, sneezing, kissing, carelessness about handkerchiefs, hands soiled with nasal secretion, imperfectly washed dishes, and the common use of towels and drinking cups.

Persons with colds are a real danger to others; but they are almost impossible to control, as they usually keep on with their daily work. A person with a cold should avoid any close contact with others, keep away from public places, cover the nose and mouth when coughing and sneezing, and avoid soiling the hands with saliva and sputum. A child with a cold should be kept out of school, both to avoid spreading the cold, and because *the first symptoms of measles and whooping-cough are those of a cold.* A person who has frequent colds should consult a doctor, since they may be due to enlarged tonsils, adenoids, or some condition which prevents him from breathing through the nose, and those should be remedied.

Causative Agent.—Until 1930 the cause of colds was a mystery, although since about 1914 a number of

scientific workers had considered it to be a filterable virus. *In* 1929 *and* 1930 *it was demonstrated conclusively that common colds are caused by an ultramicroscopic and filterable virus.*

Influenza.—In 1918–19 a terrible epidemic of influenza swept over the entire world, causing more than 10,000,000 deaths, and in the United States alone at least 450,000. Very little is known about this disease, although an immense amount of bacteriological work has been done on it. We do not even know whether it was the same as the infection which is called influenza or grippe in ordinary times, and occurs every winter as scattered cases or in small outbreaks. The mode of transmission of influenza is doubtful. Possibly crowded conditions, with droplet infection, favor epidemics.

We are still uncertain also as to the causative organism. Recently an extremely small germ, called *Bacterium pneumosintes* (Greek for "*lung-devastator*"), almost too small to be seen under the microscope, has been found in the nasal secretion of patients. This may possibly be the cause of the disease.

Epidemic influenza is one of the most contagious diseases known. When uncomplicated, it is a mild disease, but there is a special tendency to bronchopneumonia, which is responsible for most of the deaths from the disease. The same is true of ordinary grippe. The bronchopneumonia may be caused by pneumococci, streptococci, or the influenza bacillus. Thousands of deaths in the Army camps in 1918 were due to the bronchopneumonia accompanying influenza.

Public health measures, such as have been successful in controlling other infectious diseases, had absolutely no effect in the epidemic of 1918–19. Great influenza

epidemics have occurred in nearly every generation for several hundred years, and it seems probable that in course of time history will repeat itself.

Although it is impossible now to prevent influenza or grippe, it is possible in the great majority of cases to avoid the complicating pneumonia by proper care: first, by putting the patient to bed promptly and keeping him there during convalescence; and second, by protecting him from the bacteria which are known to be the cause of the pneumonia. The latter is done by carrying out the same nursing precautions as are prescribed for bronchopneumonia.

Measles is one of the commonest diseases caused by infectious agents. In spite of this fact, its cause is still unknown. In 1927 a very tiny diplococcus was reported as the cause of measles. The organism is said to be present in the filtered secretions of the nose and throat and also in the circulating blood. The disease has been transmitted to monkeys by injecting them with the filtered nose-and-mouth secretions of human cases. *It is highly probable that the causative agent is a true ultramicroscopic virus.*

Measles is *extremely contagious*. If a person who has not had measles is exposed at any age, he is practically sure to catch it. The reason that the disease is chiefly confined to children is that most persons have had it before reaching adult life.

Transmission.—The organism which causes measles does not live long outside the body. It is transmitted by direct contact, by droplet infection during coughing and sneezing, and by articles freshly soiled with the nose-and-mouth secretions. A very important fact is that *the organism is present in the nasal secretion and*

saliva before the rash breaks out. The first symptoms of the disease resemble those of an ordinary cold, and the rash does not appear until three or four days later. The disease is most infectious during this early stage; there is little danger of the patient's giving the disease after the temperature has returned to normal.

Complications.—Measles itself very seldom causes death, but complications are frequent and may be very serious or even fatal. The most common of these are bronchopneumonia, caused by pneumococci or streptococci, and abscesses in the ear, caused by streptococci. In this respect, measles resembles scarlet fever, which may be caused, in part at least, by an ultramicroscopic virus. Measles may also reduce the resistance of a child so that it falls a victim to tuberculosis. Measles is usually regarded lightly, but it is really a serious disease on account of the infections which accompany or follow it. The number of deaths due to measles is much larger than is generally realized. In the United States in 1929 it was responsible for over 2923 deaths. As with diphtheria and other infections, the younger the child, the more serious the disease. Less than half of the *cases* occur in children under five years, but 95 per cent of the *deaths* are in children of four years and under.

The number of deaths from measles is much greater among the poor than among the well-to-do, because children in comfortable homes have better nursing, are better nourished, are not overcrowded, and usually do not catch the disease at such an early age. In institutions, also, where numbers of frail young children live in close contact, an outbreak of measles is a serious matter.

Good nursing is of the utmost importance in measles to prevent the occurrence and spread of the complicating infections. Cleanliness of the nose and mouth will do much to ward off infection of the ears and lungs. If measles cases are treated in wards, the most rigid precautions must be taken to prevent the spread, not only of droplets, saliva, and other materials containing the measles organism, but also of streptococci and pneumococci from one measles patient to another. These precautions and the care of the mouth have been discussed in connection with bronchopneumonia. Terminal disinfection is not necessary for the short-lived measles organism, but streptococci are vigorous and long-lived. It is better, therefore, to sterilize the bedding and clothing, and to give the room a thorough cleaning with soap and water following measles.

Prevention.—*The prevention of measles is a difficult problem*, because the disease is most infectious during the early stages, when the symptoms are those of a cold and before a suspicion of measles has been aroused. During this period the child is usually running about or is in school, diligently spreading the infection. When a case of measles has appeared in a school or an institution, the greatest hope of limiting the spread of the disease lies in *isolating all persons having symptoms of a cold*, or known to have been in contact with the patient while he or she had the early or later symptoms. Although it is very difficult to diminish the number of cases, a great deal can be done to decrease the number of deaths from the disease:

First, by preventing the complications by means of good nursing, and

Second, by protecting very young children from infection.

Immunization.—The serum of persons who have had the disease at any time in their past continues to contain antibodies. The serum of convalescents has been in use for some years both for preventing the disease and for diminishing the severity of the attack. Recently it has been found that the whole blood of adults who have had the disease can also be used for the same purposes. The most suitable donor for whole blood is one of the parents. Both the serum and the whole blood are given intramuscularly.

Comparative studies of convalescent serum and adult whole blood have shown that while the former is more efficacious in preventing the disease, the latter modifies the attack. Immunization by convalescent serum or adult whole blood is *passive* and lasts only six or eight weeks.

To avert the attack, the serum must be given within five days after exposure. If the serum is injected in small doses after the fifth day of exposure, it does not prevent the disease but modifies its course, making it very mild. This mild attack, however, probably gives *permanent* protection.

Both the complete passive immunity and the modified attack have their fields of usefulness. If measles appears in a hospital or a children's institution, the first indication is to stop it by completely protecting the children. Very young or feeble children, and those suffering from other diseases, should also be completely protected if they have been exposed to the disease. In the case, however, of normal robust children over five years old, it is usually more desirable to obtain a modified and mild form of the disease which will give permanent immunity, rather than to protect the child absolutely for a short period.

Mumps.—The organism causing this disease is unknown, but it is spread by the secretions of the mouth, nose, and throat. The disease is difficult to control because the incubation period may be as long as three weeks, and the patient may give the disease for some time before the symptoms appear.

Chickenpox.—This disease is included here, although the ways in which it is spread are uncertain. The organism causing it is also unknown, but it is contained in the "pock," or eruption.

CHAPTER XXVI

THE ULTRAMICROSCOPIC VIRUSES (Continued)

Anterior poliomyelitis: virus; transmission and prevention; immunity; antisera—*Rabies:* diagnosis; immunity; practical procedure—*Psittacosis*—*Bacteriophage:* varieties; isolation; properties; therapeutic use.

Anterior Poliomyelitis.—This infection is attracting much attention at present and through its study important advances are being made not only as to this disease, but also as to the nature of ultramicroscopic viruses in general. As our knowledge is advancing with comparative rapidity, statements which represent the best research of today may be outmoded in a few years.

Anterior poliomyelitis (from its derivation literally *inflammation of the gray matter of the anterior horns of the spinal cord*) is an acute febrile disease which results in an injury or destruction, more or less extensive, of the motor cells of the anterior horns of the cord (Fig. 87). Like a number of diseases caused by ultramicroscopic viruses, it is in most cases characterized by a sudden onset, with headache, chills, fever, and vomiting. The patients often exhibit extreme irritability, also pain when being moved, and, characteristically, the muscles of the neck are held rigid. Following the febrile period, there usually appears a paralysis of the legs, and in some cases also of the arms and other muscles. If the paralysis extends to the muscles of the diaphragm, death may quickly ensue from respiratory failure.

The Poliomyelitis Virus.—The infectious nature of anterior poliomyelitis was known as early as 1905. In 1909 scientists succeeded in producing the disease

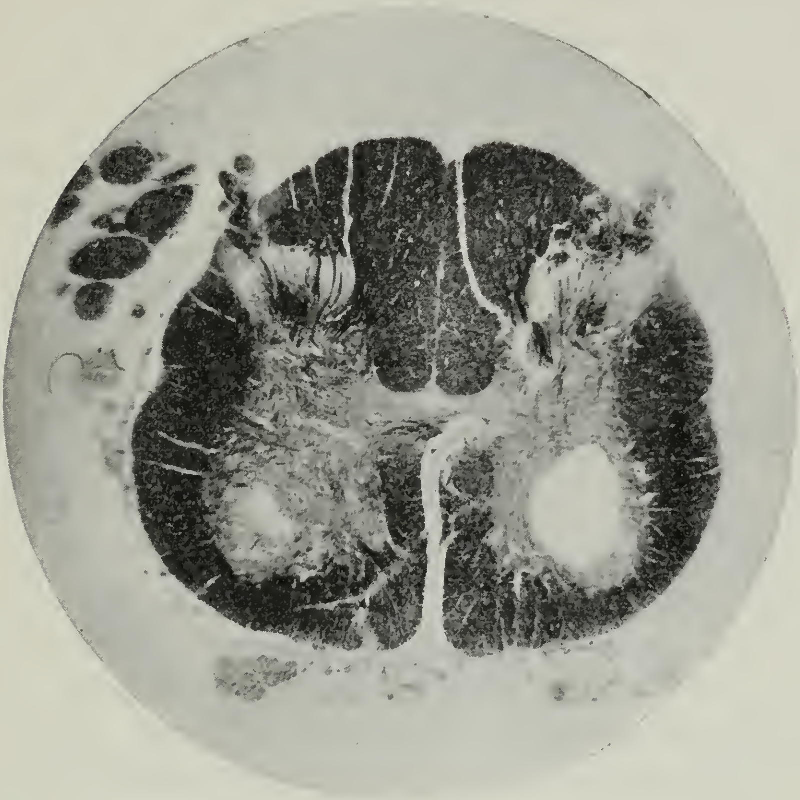


Fig. 87.—The results of acute anterior poliomyelitis. A cross section of the cord in the lumbar region. The gray matter of a large area in the left anterior horn has been completely destroyed by the inflammation, leaving a hole. The result of this lesion would be paralysis of the left leg. In the right anterior horn is an area of partial degeneration, as evidenced by the light spot. Compare with Fig. 77. (From Wechsler "Clinical Neurology.")

in animals by inoculating them with spinal cord from fatal cases of poliomyelitis. Since then an enormous amount of effort, time, and money has been expended to discover the causative agent of the disease and ways

to prevent or cure it. Very valuable data have been accumulated.

The virus localizes in the brain, spinal cord and certain nerves, and thus causes the pain and paralytic symptoms referred to. No one has been able to cultivate from the blood, brain, or spinal fluid of patients any ordinary bacteria which could be the cause of the malady. The celebrated scientists Flexner and Noguchi, working at the Rockefeller Institute in New York,

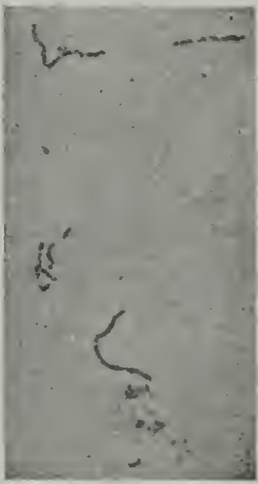


Fig. 88.—The microorganism of epidemic poliomyelitis. Chains and pairs of globoid bodies; × 1000. (Flexner and Noguchi.)

succeeded in cultivating from infected brains, tiny organisms which they called *globoid bodies.* These appear to be very definitely related to the disease, but whether they are actually the virus or merely something to which the virus is attached, cannot be definitely stated. In any case, the causative agent, whatever it may be, passes readily through porcelain filters which withhold the tiniest bacteria, and is therefore classed as an *ultramicroscopic virus.*

It is quite resistant to some disinfectants. It may infect after fifteen months storage in 0.5 per cent phenol

and after six years in 50 per cent glycerin. Exposure to a temperature of 50 C. for thirty minutes inactivates it completely. In this latter respect it resembles practically all of the other filtrable viruses which affect man.

Transmission and Prevention.—The virus of poliomyelitis is found in the nasal secretions and probably mixes in the saliva. Transmission of the virus from person to person therefore must be much the same as in scarlet fever, diphtheria, or pneumonia. Sneezing, coughing, the use of common drinking and eating utensils improperly washed may thus transmit the disease. It is thought by many that there may be some other means of transmission—possibly some insect which thrives in the late summer and fall, the season when the disease is most prevalent.

Patients may harbor the virus in their nasopharynx from a week before onset of symptoms till two weeks or more after the acute attack. A very important means of spreading the disease is the *healthy carrier.* The virus appears to live for some days or weeks outside the body, and a few instances have been reported of the disease being transmitted by means of raw milk.

The methods involved in the prevention of transmission of the disease from a patient are obvious. As to the protection of healthy children, the most that can be advised at present is to diminish human contacts, especially in times of epidemic. The virus is evidently very widely distributed.

Immunity.—A considerable number of the adult population in congested communities have had sufficient infection to immunize them without producing symptoms. This is shown by the fact that their serum has the power to neutralize the virus, although the individ-

uals give no history of the disease or even of exposure to it. It is possible that the majority of city children at some time have contracted the infection in a very mild form. Poliomyelitis is another example of the *ability of subclinical infections to confer active permanent immunity.* The majority of persons exposed do not contract the disease. An individual who has once had the disease is immune for the rest of his life.

Antisera.—*Convalescent serum* is obtained from patients over ten years of age two or three weeks after recovery from the febrile stage. *Adult immune serum* is obtained from adults known to have recovered from the disease. If given early, these sera appear to have considerable value in preventing the development of paralysis. They are given *intraspinally.* The use of *parents' blood,* as in measles, may be useful in an emergency. Its use is based on the theory that one or both parents may have had a subclinical infection. Efforts are being made to develop a powerful and safe *immune serum in horses* by injecting them with brain and cord tissue known to contain the virus.

Rabies (Hydrophobia).—This is primarily a disease of animals, which is transmitted to man usually as a consequence of the saliva of rabid animals gaining entrance to wounds caused by bites or scratches. It is caused by a *filterable virus,* which particularly affects the central nervous system, to which it is conveyed from the wound chiefly by the path of the nerve trunks. The disease in man is very terrible, passing through periods of depression and excitement, usually with clear consciousness, and attended by painful spasms, to a stage of paralysis. If the symptoms have once appeared, death is practically inevitable.

Diagnosis.—The brains of animals and human beings dead of rabies contain certain peculiar microscopic bodies (Fig. 89), called *Negri bodies,* after the Italian investigator who discovered them in 1903. The nature of these bodies is unknown (they may be parasites), but their specific association with rabies now appears proved. The examination of the brains of suspected

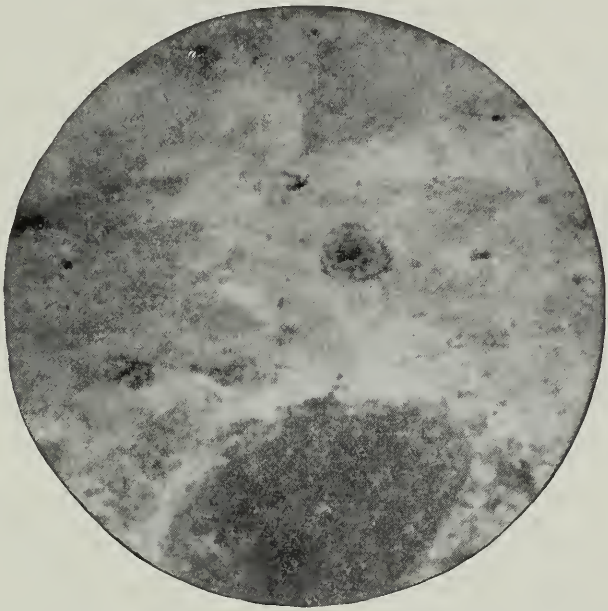


Fig. 89.—A Negri body is seen a little to the right of the center of the field. The background is brain tissue, and the granular object in the lower part of the field is a nerve cell. Magnified 2000 times. (Williams and Lowden.)

animals for their presence is an extremely important method of diagnosis.

Immunity.—Formerly a fairly common disease, rabies has now become a rare disease among human beings in civilized countries because treatment with the *living weakened virus* (Chapter VIII and Fig. 32) is now generally given to all persons who might by any possibility have been infected by bites. The method was

originated by Pasteur (1881–1886) and results in *active immunity*.

Practical Procedure.—When a person is bitten by a dog suspected of being mad, the Pasteur treatment should be started without delay. *Do not kill the dog unless it is diagnosed rabid by a competent veterinarian.* If it is caught, hold it for observation for at least two weeks. If it has rabies, it will show unmistakable symptoms, and may then be killed and the brain examined for Negri bodies. If it shows absolutely no symptoms, it may be released, and the victim may then discontinue the Pasteur treatment. His mind will be much more at ease to know the dog to be free from rabies than if the dog had been killed with the suspicion still upon it. *If the animal has already been killed, send the head, packed in ice, immediately to the laboratory of the State or City Department of Health*, for examination for Negri bodies.

Pasteur treatment reduces fatality from nearly 100 per cent to about 1 per cent. It is absolutely harmless.

Psittacosis (*"Parrot Fever"*).—This disease is caused by a *filterable and ultramicroscopic virus* which has not as yet been cultivated in ordinary bacteriological media. The virus nature of the disease was proven in 1930. The virus resembles many other such viruses in being rather easily inactivated by heat and in being slightly more resistant to some disinfectants than most vegetative forms of bacteria.

The virus attacks parrots and related species of birds, causing diarrhea, sneezing, and a generally sick appearance. The disease was probably first brought to the United States by infected birds. It has also appeared in European countries. It is readily transmitted to

human beings by the feces and the exudate from the nostrils and mouth of the sick parrots. In human beings it causes a generalized reaction with chills, fever, headache, and vomiting. It especially attacks the lungs, causing a form of broncho-pneumonia. The disease is frequently fatal, and during 1929 and 1930 several bacteriologists lost their lives as a result of studying the virus.

Transmission.—The nose and mouth secretions of infected human beings transmit the virus. Persons ill with the disease should be isolated and every precaution taken to prevent their secretions from reaching susceptible people. All parrots or similar birds suspected of having the disease should be killed and incinerated, and their cages either burned or soaked in lysol or other disinfectant solution. The United States Government prohibited the importation of parrots and related species after it was known that these were causing illness and death.

The Bacteriophage.—In 1915 a British scientist named Twort observed that certain colonies of staphylococci growing on agar plates often tended to become "glassy" and transparent. The cocci in such colonies would not grow well when transferred to other media. When pure, vigorous, normal cultures of the cocci were contaminated with a few cocci from "glassy" colonies, the normal cocci also became glassy. It seemed as if the "glassiness" were due to a disease of the bacteria caused by something which came from the first glassy colonies and which, like other disease germs, could be communicated to healthy bacteria.

In 1917 a French bacteriologist, named d'Herelle, noticed that if feces from certain dysentery patients

were emulsified in water or broth and the fluid part then passed through a porcelain filter, the fluid that passed through, although entirely free from bacteria, contained something which would dissolve young, growing, normal dysentery bacilli in broth cultures. By transferring even a very tiny quantity (perhaps a millionth of a cubic centimeter) of the dissolved culture after filtering it, to a new culture, the same process could be made to occur, and so on through an indefinite number of transfers. d'Herelle believed the agent responsible for the dissolution of the bacteria to be a filterable virus causing a disease of the bacteria. After much investigation and debate, however, no one is sure whether it is really a living virus or a sort of enzyme which is produced under peculiar circumstances by the bacteria themselves—a "suicide enzyme" so to speak—more properly called an *auto-lytic* enzyme. d'Herelle named the virus the *Bacteriophage*. The phenomenon of the dissolution of bacteria by this agent is called *bacteriophagy* or the *Twort-d'Herelle phenomenon*.

Varieties.—Since the original observations of Twort and d'Herelle, bacteriophages have been discovered which attack a great variety of bacteria. Usually a given bacteriophage will attack only a single kind of bacterium, but this is not always the case. Some bacteriophages can be trained to attack more than one bacterium, just as some bacteria can be induced to infect certain animals which they do not ordinarily attack. Whether this apparent change is due to the same bacteriophage adapting itself to the new bacteria, or simply to a predominance of one bacteriophage over another, in a mixture, under new conditions, is at present a hotly debated point.

Isolation.—It is not difficult to find bacteriophages. The lytic (dissolving) agent is very frequently found in the feces of animals, birds, and insects. One emulsifies these, filters the emulsion through a porcelain filter, and puts a drop or two of the filtrate into very young broth cultures of a variety of bacteria, especially members of the coli-typhoid-dysentery group. After two or three hours of incubation, one or more of the cultures may be observed to clear up a little. This is due to lysis (dissolution) of many of the young bacteria by the growing bacteriophage. If a drop of this culture is spread on an agar plate and incubated twenty-four hours, there will be found in many cases, either no growth at all, or a smooth growth "eaten" away here and there, or punctuated or pierced with varying numbers of little holes. D'Herelle's explanation of this phenomenon, the so-called "plaque formation," is that each of the little holes or plaques represents a colony of the bacteriophage, which multiplied at that spot, living upon and destroying the growing bacteria in the vicinity. Whether or not this is the correct explanation, it is plausible and widely accepted. It must be pointed out however, that practically all of d'Herelle's theories concerning the bacteriophage are still hotly disputed, and no definite statements can be made as yet.

Properties.—Bacteriophage is filterable and invisible with the microscope. It has been cultivated only in contact with living bacteria. It is somewhat more resistant to chemical disinfectants than most vegetative bacteria and will live a long time sealed up in test tubes. In these respects it resembles filterable viruses very closely.

Therapeutic Use.—D'Herelle conceived the idea of introducing bacteriophage into the human body to cure disease. His theory was simple. If, for example, a person has typhoid fever, then feed him, or inject into him, a small amount of a strain of bacteriophage which will dissolve and kill the typhoid bacilli causing the infection. If a person has boils, then inject the proper sort of bacteriophage into the boils, or apply dressings wet with filtrates containing the bacteriophage. According to d'Herelle's ideas, once the bacteriophage starts to attack the bacteria causing the disease, it multiplies at the expense of the bacteria and kills them all just as it does in the test tube.

This theory was given a wide application and bacteriophage treatment was tried in many different diseases. Many physicians, especially in Europe, claimed to have obtained marvellous results; others became completely discouraged with bacteriophage as a therapeutic agent. The present status of the treatment is very uncertain.

CHAPTER XXVII

INSECT-BORNE DISEASES

Biological transmission of disease by insects—Historical note—Common diseases transmitted by biting insects—Prevention of insect-borne diseases—*Malaria:* the parasite; its life in man and in the mosquito—The malaria-bearing mosquito—Diagnosis of malaria—Carriers—Malaria as a social problem—Prevention of malaria—*Rickettsia diseases*—Rocky-mountain spotted fever.

Biological Transmission of Disease by Insects.—In Chapter X it was stated that disease organisms are transmitted by insects in two ways, mechanical and biological, and some discussion was given of the mechanical distribution of bacteria by flies. In this chapter we shall take up the biological transmission of disease by insects, principally through a consideration of the most common of this type of infections-malaria.[1]

A parasite is a creature which lives on another creature, getting its food from it but giving nothing in return. Man and other animals are afflicted with various parasites. The bacteria which live on and in the body are parasites, and so are lice and tapeworms. The creature on which the parasites live is spoken of as the *host*, although his guests are neither welcome nor paying.

In the true insect-borne diseases, *i. e.*, those transmitted biologically by insects, the organisms undergo one stage of their development in the insect and another

[1] For a continuation of this discussion see Chapter VI of Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

stage in man. The insect is thus necessary for the life of the parasite and is the means of conveying the infection to man. Many of these diseases are caused by parasites belonging to the animal kingdom and having a complicated cycle of development. The organisms are harmless to the insects.

These diseases prevail especially in warm regions where insects abound, and also in temperate climates under conditions of uncleanliness and crowding, in

Fig. 90.—The spotted-fever tick, male (left) and female (right) enlarged 3½ times. (From Herms' "Medical and Veterinary Entomology." Courtesy of The Macmillan Company, Publishers.)

which vermin, such as lice and bedbugs, flourish. Their mode of transmission is much more complicated and harder to understand than that of the diseases which are transmitted directly from man to man.

Historical Note.—The fact that diseases may be transmitted through the bites of insects was first proved in 1893 in connection with Texas fever, a disease of cattle transmitted by ticks. In 1895, Sir Ronald Ross, an Army physician in India, demonstrated the transmission of malaria by mosquitoes. The parasite had, however, been seen in the red corpuscles as early as 1881 by Laveran, a French Army surgeon in Algeria. In 1900, the transmission of yellow fever

Fig. 91.—The body louse (*Pediculus vestimenti*), female, enlarged 15 times. The body louse is larger than the head louse. (From Todd and Sanford's "Clinical Diagnosis.")

Fig. 92.—The flea, *Pulex irritans*, male, enlarged 15 times. (From Todd and Sanford's "Clinical Diagnosis".)

by a particular variety of mosquito was proved in Cuba by Drs. Walter Reed, James Carroll, Aristides Agramonte, and Jesse Lazear of the United States Army. The discoveries of the methods of transmission of malaria and yellow fever are among the most brilliant in medicine and have been epoch-making in their results.

Fig. 93.—The bedbug (*Cimex lectularius*) male enlarged 5 times. (From Todd and Sanford's "Clinical Diagnosis".)

Common Diseases Transmitted by Biting Insects.—The commoner diseases carried by biting insects may be tabulated as follows:

Mosquitoes—
- Malaria,
- Yellow fever,
- Dengue.

Bed-bugs—
- Relapsing fever (?)

Ticks—
- Relapsing fever,
- Rocky mountain spotted fever (see also *Typhus*),
- Texas fever.

Rat fleas—

Bubonic plague.[1]

Lice, ticks and fleas—

Typhus fever and related diseases.

Prevention of Insect-borne Diseases.—The prevention of this type of infection depends upon a knowledge of the disease in man, of the life cycle of the parasite, and of the structure and habits of the insect concerned. The extermination of rats, flies, and biting insects of all kinds is desirable from a sanitary standpoint. Extermination is not always possible, but it is feasible to keep insects and rats out of our houses and away from our bodies by simple measures of screening, fumigation, and cleanliness. In the case of insects, the most effective measures are those which destroy their breeding places. For rats and household vermin a very important method is to starve them out. As will be discussed in connection with malaria, insect-borne diseases may be controlled by *attacking the insect, the parasite in the human host, or both.*

Malaria.—Nurses in the tropics and in all warm climates become very familiar with this disease. It is present in temperate climates all over the world, and in the past it has made some parts of the earth, like Panama, almost uninhabitable. The countries where it prevails have, within recent years, been fighting it on a large scale. Due in the beginning to the initiative of the International Health Board and the Rockefeller Foundation, the disease in this and other countries has been very much reduced in recent years. Nevertheless, it still remains one of the most widespread and frequent of all communicable diseases. It is estimated

[1] This is probably not a case of true biological transmission.

that in this country there are a million cases a year. In 1929 it caused 4084 reported deaths.

The Malarial Parasite.—The disease is caused by a very simple form of animal life, a protozoan (see Chapter on Protozoa). Its life history is, however, quite complicated. It has *two stages of development, one of which is passed in the human body, the other in the mosquito.* Both man and the mosquito are hosts of the organism, and both are necessary for its life and

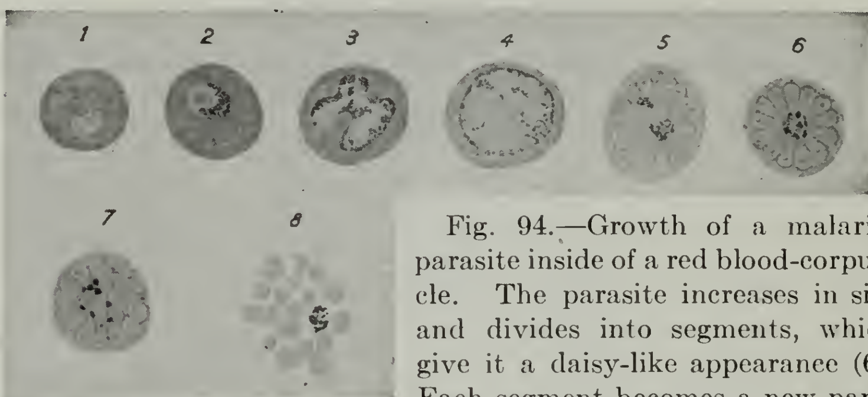


Fig. 94.—Growth of a malarial parasite inside of a red blood-corpuscle. The parasite increases in size and divides into segments, which give it a daisy-like appearance (6). Each segment becomes a new parasite. Finally the red corpuscle bursts and the young parasites escape into the circulating blood (8). This is when the chill occurs. They are now ready to enter fresh corpuscles. The black material is pigment formed from the hemoglobin of the red corpuscle. (Thayer and Hewetson.)

reproduction. Unless it can pass from man to the mosquito, and from the latter back again to man, it will die out. It is transferred from man to the mosquito and back again through the bite of the mosquito.

Life in Man.—The mosquito, in biting, injects the parasites into the blood of its victim through its bill, which is a sort of natural hypodermic syringe. The parasites immediately enter red corpuscles and grow within them (Fig. 94, 1–7). The parasite within the corpuscle is in active movement. It multiplies within

the red cell forming a number of small bodies or segments (Fig. 94, 5–7). Finally the affected corpuscle breaks up, and the segments escape into the circulating blood (Fig. 94, 8). Each segment is a new, active parasite and no sooner gets out into the blood than it attacks another red corpuscle, and in turn multiplies.

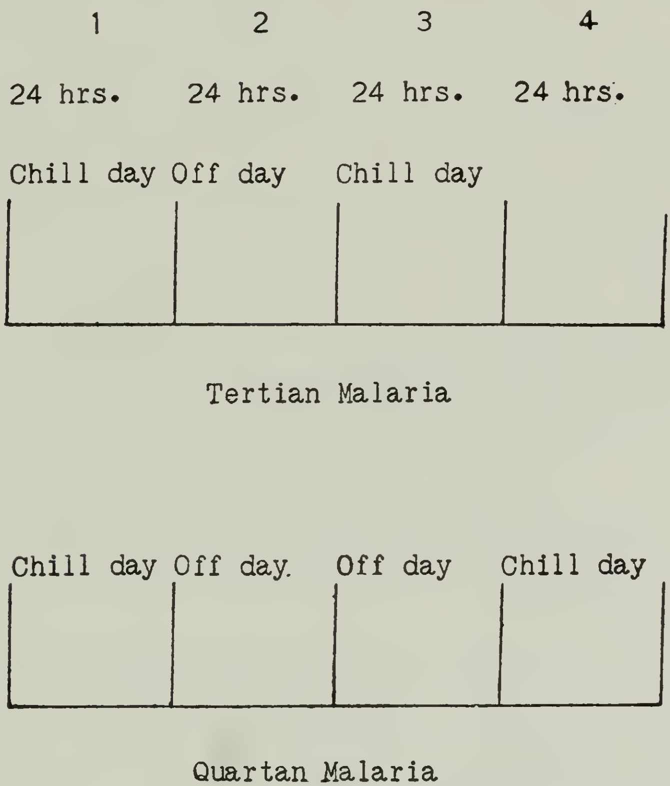


Fig. 95.—Diagram of the occurrence of chills in tertian and quartan malaria.

In this way the blood is soon teeming with the parasites, and the patient becomes anemic and weakened from the loss of so many red cells and from the poisonous products formed by the parasites.

The parasites are present in the blood in great groups, all the individuals of which divide and burst out of the

corpuscles at about the same time. This process causes the chill and fever. *A chill means that a fresh crop of parasites has matured and entered the circulation.*

There are three forms of the malarial parasite. The first and most common requires forty-eight hours to complete its development within the red cells. The chill will therefore occur at intervals of forty-eight hours, or every third day. This is called *tertian* (*third*) *fever* (Fig. 95). The second form of parasite requires seventy-two hours for development, and groups of parasites ripen every fourth day. This kind, which is comparatively rare, causes *quartan* (*fourth*) *fever.* The third form, *estivo-autumnal,* requires from twenty-four to forty-eight hours for development. The temperature curve of this fever is irregular, and chills may occur every day or be entirely absent. It is called estivo-autumnal because it occurs in the late summer and fall. It is more severe than the other forms of malaria and is less easily controlled by quinin. Most of the fatal cases of malaria are caused by the estivo-autumnal parasite.

Not infrequently a person may be infected with two or even three types of parasite and have chills every day, or two days in succession and then skip a day and have two more days of chill.

Life in the Mosquito.—When a mosquito bites a person who has malarial parasites in his blood, it takes these in with the blood which it sucks. The parasites undergo further development in the wall of the mosquito's stomach, a stage of development impossible in man but necessary for the continued existence of the parasite. Finally, after multiplying and moving about for some days inside the mosquito, they reach the

mosquito's salivary glands, and from there are injected into man when the insect bites. The life cycle is thus complete. The period of development of the parasite in the mosquito is about twelve days; that is, a mosquito which has bitten a malaria patient cannot transmit the disease to another person until the end of that time. A mosquito once infected remains so for the rest of its life, which may be two months or more.

The Malaria-bearing Mosquito.—There are numerous species of mosquitoes, but only a very few carry the parasites of human diseases. The kind which transmits malaria is called *Anopheles* (Fig. 96). Only

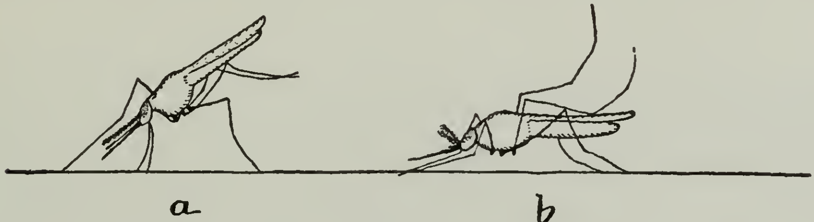


Fig. 96.—Characteristic attitudes of mosquitoes at rest: *a*, The malaria mosquito with body at an angle to the surface; *b*, the harmless mosquito with body parallel to the surface. (Deaderick, "A Study of Malaria.")

the female bites mankind, and she does so only because blood is necessary for egg-laying.

Mosquitoes pass through four stages of development (Fig. 97 and 98): the egg; the larva or "wiggler"; the pupa, and the fully developed insect. The first three stages take place in water.

The Anopheles mosquito may be recognized as she bites. First, she stands in a position like that indicated in Fig. 96*a*. The harmless mosquito stands as shown in Fig. 96*b*. The Anopheles mosquito usually has spots of silver or gray on the wings and often gray bands on the legs. There are several varieties of mosquitoes

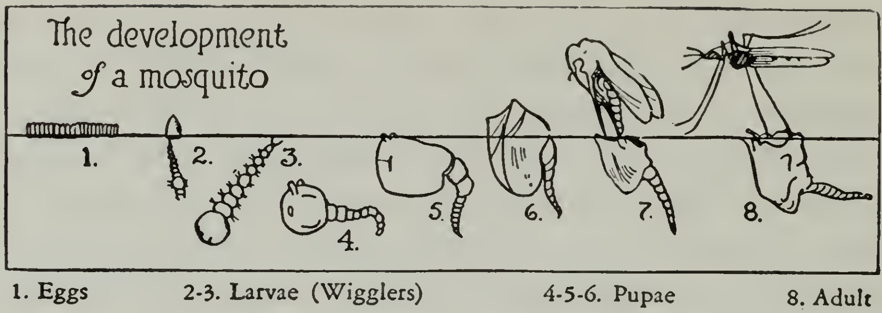


Fig. 97.—The eggs are laid in clusters on the surface of still water. In about a day the "wigglers" (Fig. 98) come out of the eggs and swim about in the water. In about a week they develop into "pupae" (the Latin word for "dolls"), which in turn grow into the adult insect. About two weeks from the time the eggs are laid, the pupa skin splits, the full-grown mosquito emerges, stretches and dries his wings, and flies away. (From American Public Health Association.)

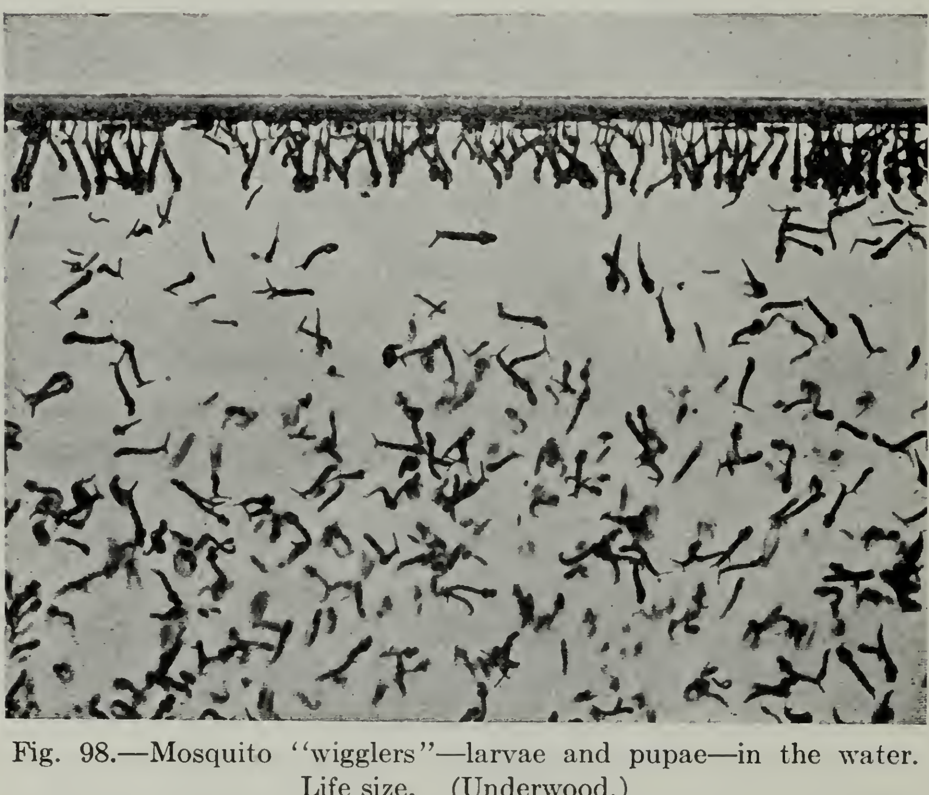


Fig. 98.—Mosquito "wigglers"—larvae and pupae—in the water. Life size. (Underwood.)

and the markings are not as plain on some as on others. The harmless varieties are brownish or brown-gray.

Anopheles mosquitoes are recognized by a number of other means. Their eggs and the immature forms offer points for recognition. Students who are interested are referred to the larger textbooks.

Fig. 99.—Where mosquitoes breed by millions. (Howard.)

Diagnosis of Malaria.—The laboratory diagnosis of malaria is made by spreading a small drop of the patient's blood on a slide and either examining it in the fresh state or staining it with Wright's stain, a special stain used for blood smears. The parasites can be seen in or upon the blood cells and may have any of the appearances seen in the illustration, depending on the stage of their development in the red cells.

Carriers.—A considerable proportion of persons in a region where there is much malaria harbor the parasites in their blood without having symptoms of the disease. Some of these people have had attacks in the past, but many are unaware of ever having had the disease. The parasites may remain alive in the spleen and other organs for years. About 10 per cent of healthy adults in malarious districts and a much larger proportion of children carry the parasites. It is apparent that mosquitoes biting these people will become infected and pass the organisms along to healthy persons. These carriers are much more numerous than the actual cases of malaria, and they are one of the most, if not the most, important means of keeping the disease alive. If the blood of all infected persons in a community could be freed of parasites through the use of quinine, malaria would disappear, even though Anopheles mosquitoes were still present. On the other hand, if the mosquitoes were exterminated, no new persons would become infected, no matter how many carriers there might be.

Malaria as a Social Problem.—If a person has once been infected, it is quite difficult to free him completely from malarial parasites. Unless quinine treatment is pushed vigorously during the attack and kept up for some time after recovery, the disease will continue to break out at intervals. Persons having chronic malaria are semi-invalids; they are weak, anemic, and listless, unable to work much, and without ambition. Child carriers remain undeveloped and backward. *The disease is thus of great social and industrial importance.* Where many persons are affected, the effect is apparent in the community life. Such communities are of low

grade, shiftless, poverty-stricken, and of small working capacity. In regions where malaria prevails extensively, it is a great obstacle to social progress and industrial efficiency, and its suppression is the most important sanitary work that can be undertaken. Regions in which malaria has been controlled show a marked improvement socially and industrially.

The Prevention of Malaria.—Malaria is entirely preventable. The disease is attacked along three lines; first, *the extermination of mosquitoes;* second, the preventing of mosquitoes from getting at persons, *by the use of screens;* and third, the *destruction of the parasites in human beings* through the use of quinine.

Malaria prevails where mosquitoes find congenial conditions of life; that is, in lowlands, and near swamps and bodies of stagnant water (Fig. 99). It is largely a rural disease. The name malaria means literally, "bad air," and was given to the disease because it used to be thought that there was some unhealthful condition of the air in marshes and lowlands which caused the disease. We now know that malaria is associated with low-lying places because mosquitoes live there.

The destruction of the breeding places and eggs of mosquitoes is the most permanent and thorough way of fighting malaria. Breeding places are destroyed by draining swamps, filling in pools, and clearing the edges of ditches and streams. The developing eggs are killed by spraying coal oil on the surface of the water. Bodies of water in which mosquitoes breed may be stocked with minnows which eat the eggs. This is an excellent method where possible. Large swamps and bodies of shallow, stagnant water have been successfully sprayed with oil from aeroplanes.

Screening is of much value if it is carefully and intelligently done. Malaria patients should of course be protected from mosquitoes to prevent spreading their infection further.

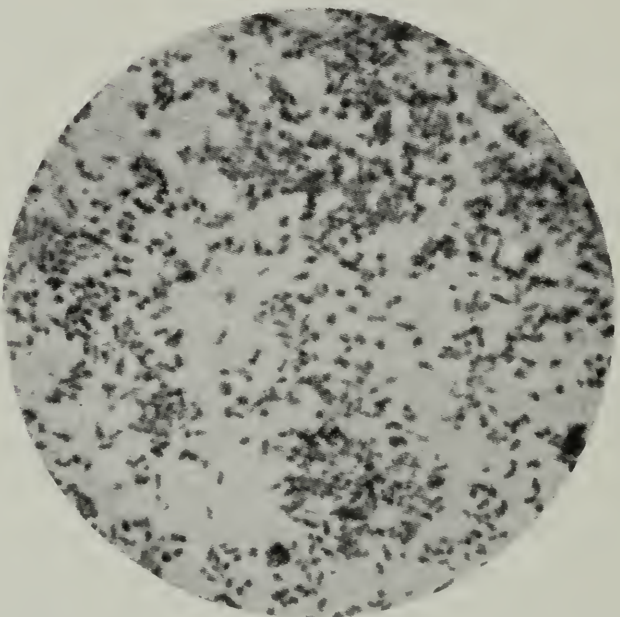


Fig. 100.—The variety of rickettsia which is the probable cause of typhus fever. Magnified 2000 times. Smear from the intestine of a louse (Fig. 91), experimentally infected by biting a typhus patient. The rickettsia bodies appear as granules and short rods, arranged singly, in pairs, or as short chains. (From Wolbach, Todd and Palfrey "The Etiology and Pathology of Typhus," Harvard University Press, Publishers.)

Quinine has a specific action on the malarial parasite just as arsphenamine has on the Spirochaeta pallida. After an acute attack it is of the greatest importance that quinine should be continued in sufficient doses for some time, in order to kill all the parasites and thus prevent the patient from developing into a carrier. A course of quinine treatment is also necessary for disinfecting carriers. Persons living in malarious regions

take quinine regularly to prevent the development of the disease.

Permanent success in controlling malaria will follow a combined attack on the mosquito and on the parasite in human beings. The suppression of malaria is largely a financial problem. Any community can rid itself of the disease if it can and will spend enough to destroy the breeding places of the mosquito and to find and disinfect human carriers.

Rickettsia Diseases.—There is a group of diseases generally called the *Typhus Group*, which resemble each other closely and are probably caused by tiny bacteria-like organisms designated *Rickettsiae* (Fig. 100) after their discoverer, Ricketts. The organisms vary greatly in shape from minute diplococci to long filaments. They have probably never been cultivated on artificial media. They occur in the cells of various lining membranes of the body. As yet, it is impossible to classify them either with the bacteria or the protozoa, and therefore they are segregated into a special group. All of them have an insect host which acts as a transmitting agent.

The rickettsia diseases are best represented by European typhus and Rocky Mountain spotted fever. There is also a recently described Brazilian typhus and an American and Mexican typhus. There are also other variations of the disease, all probably caused by different varieties of rickettsiae. The rickettsiae are transmitted by the bites of ticks, fleas or lice, the species of insect depending on the particular rickettsiae involved.

Rocky Mountain Spotted Fever.—This disease is caused probably by a visible organism called *Derma-*

centroxenus rickettsi. These organisms are usually found in the gut of certain "wood ticks" which transmit the disease by their bite. They are not true bacteria nor are they filterable or ultramicroscopic. Some workers entertain doubt of their being actually the cause of the disease.

Rocky Mountain spotted fever begins with a sensation of drowsiness, headache and muscular pains, chills and sometimes vomiting. Within two or three days small hyperemic and hemorrhagic spots appear in the skin, and there may be bleeding from the nose and mouth.

The disease, or one very closely resembling it and probably identical with it, has recently been found to occur in the Southeastern States as well as in the Western states from which it gets its name. The Eastern form is milder.

Workers in the United States Public Health Service have developed a vaccine composed of infected ticks treated by certain special procedures, which either prevents the disease or greatly modifies its course. One attack of the disease confers life-long immunity.

CHAPTER XXVIII

THE PATHOGENIC PROTOZOA

Protozoa: structure and biology; classification—*Entameba histolytica*—Amebic dysentery: transmission; carriers; diagnosis—*Giardia intestinalis*—*Trichomonas hominis*—*The trypanosomes*—*Plasmodium vivax*—*Balantidium coli.*

Protozoa.—The protozoa (proto = *primitive;* zo = *animal*) are *single-celled animals.* They bear a relation to the animal kingdom similar to that of the bacteria to the vegetable kingdom. They are, in general, considerably larger than the bacteria and their life activities and structure are somewhat more complicated. Hundreds of kinds of harmless protozoa live in much the same situations in the outside world as the thousands of varieties of harmless bacteria. Only a relatively few kinds of protozoa are harmful to man, and it is the more important of these which we shall describe very briefly in this chapter. Students interested in learning more of the protozoa should consult a textbook on medical bacteriology or protozoology.

Structure and Biology.—The protozoan cell resembles the diagram shown in Chapter I (Fig. 1), much more closely than does the bacterial cell. There is always a well defined nucleus, which can be seen clearly with the microscope. There is a definite cytoplasm and cell wall, and there are usually small granules which have various functions connected with motion, digestion, and reproduction.

Protozoa multiply very much as do bacteria; that is, by dividing into two. They usually divide lengthwise rather than crosswise like the bacteria.

Many of the protozoa pass through a definite and readily demonstrable series of stages in their development and thus differ greatly from the bacteria. These *life cycles*, as they are called, differ for each species and often are exceedingly complicated. A very good illustration of a protozoan life history is that of the malarial parasite, which is a protozoan. (See Chapter XXVII.) In the case of the malarial and some other protozoa, especially those which live in the blood, it is necessary for the parasite to *live on one or more insect hosts before it is mature and ready to infect man and reproduce again.* The insect is called the *intermediate host.* In the case of malaria the intermediate host is the Anopheles mosquito. Usually protozoa multiply during one stage of their life cycle by sexual means. This differs with different organisms.

All of the protozoan parasites of man which we shall study in this chapter are *motile.* The means of motility is different in each group and is used as a *basis of classification.*

Classification.—There are four great groups of protozoa. At least one member in each group attacks mankind. They are as follows:

Class I. Rhizopoda (move with pseudopods).
- A. Entameba histolytica—causes amebic dysentery.

Class II. Mastigophora (move with long, whiplike lashes called *flagella*).
- A. Intestinal parasites.
  1. *Giardia intestinalis*—causes mild diarrhea and ulcers of intestine.
  2. *Trichomonas hominis*—causes mild diarrhea (?).
- B. Blood parasites.

1. *Trypanosoma rhodesiense*—causes African sleeping sickness.
2. *Trypanosoma gambiense*—causes African sleeping sickness.

Class III. Sporozoa—(move with flagella in immature stages only).

1. *Plasmodium* (*vivax, malariae, falciparum*)—cause different types of malaria. (See Chapter XXVII.)

Class IV. Infusoria—(move with cilia).

1. *Balantidium coli*—causes mild diarrhea (?).

Entameba Histolytica.—The *Entamebae* are one species of the large group of organisms called *amebae*. These organisms have no particular form, but are continually changing their shape from round or oval to very irregular shapes with protrusions and finger-like processes sticking out from various portions (Fig. 3). They move by means of these finger-like processes which are called *pseudopodia* (pseudo = *like;* pod = *foot*).

There are several types of amebae which live in the intestine. The harmful type bears the name *Entameba histolytica* (ent = *inside, i. e.*, parasitic, to distinguish it from the species which live free in the outside world, frequently in stagnant water; histo = *tissue;* lyt = *to dissolve*). It was first accurately described as the cause of dysentery in 1875.

The organisms (Fig. 101) feed upon the cells which line the intestine and upon red blood corpuscles. They take in food in exactly the same manner as do the leucocytes, and indeed resemble the leucocytes in many respects.

Amebic Dysentery.—Entameba histolytica causes a severe infection called amebic dysentery, associated with ulcers in the large intestine.[1] The parasites often bur-

[1] The student must distinguish clearly between amebic and bacillary dysentery (Chapter XVI).

row through the lining and perforate the intestinal wall, and the patient may then die of peritonitis caused by escape of the bacteria in the feces into the abdominal cavity. The entamebae often migrate upward into the liver and burrow through the diaphragm into the lungs, eating out huge cavities wherever they go. *Emetine* has a specific effect on the parasite, comparable to that of quinine on the malarial organism, and of arsphenamine on the treponema pallidum.

Fig. 101.—Entameba histolytica as seen in a fresh stool. The organism shows a nucleus in the center, numerous vacuoles, and three red corpuscles which it has ingested. Below are three blunt ameboid processes (pseudopods), parts of its protoplasm which it puts out as it moves. Magnified 600 times. (Kruse and Pasquale.)

Amebic dysentery is common in all warm regions. It is frequent also in the Southern parts of the United States and is not very rare even in the North.

Transmission.—The organisms are voided in the feces. They have the property of forming spore-like cysts which remain alive for some time in feces or in polluted soil, water or dust. Anything contaminated with infected human feces may transmit the cysts. This is an especially common occurrence in the Orient and other places where human sewage and feces are used for fertilizer. Fresh vegetables, as lettuce and

celery, may then very readily have live amebae cysts upon them when eaten.

Carriers of *E. histolytica* exist in all populations and these of course are dangerous sources of infection. In countries where modern sanitation in regard to disposal of sewage and feces is effective little amoebic dysentery exists.

Diagnosis.—The disease may be diagnosed in the laboratory by examination of the stools of a patient with the microscope. The cysts and vegetative forms may then be found. The amebae are easily cultivated on certain special media.

Giardia Intestinalis.—These organisms have a very fantastic appearance (Fig. 102; C, C′ and D). They are about the size of the smaller leucocytes. They live in the intestine and fasten themselves to its lining by means of a sucker-like organ. They feed on the body fluids.

Giardia intestinalis causes mild diarrheas and may often be found in normal people. It is not a very dangerous organism. Like the amebae, it can form cysts and is disseminated with fecal material. Diagnosis is made by examination of the stools with the microscope.

Trichomonas Hominis.—These are pear-shaped protozoa which are a little smaller than Giardia intestinalis. They do not cause any severe lesions in the intestine and indeed it is questioned by many whether they are at all harmful. They form cysts and are disseminated in the feces. (Fig. 51; E.)

Treatment is easy and effective for both Giardia and Trichomonas infections. Carriers of both organisms are not uncommon.

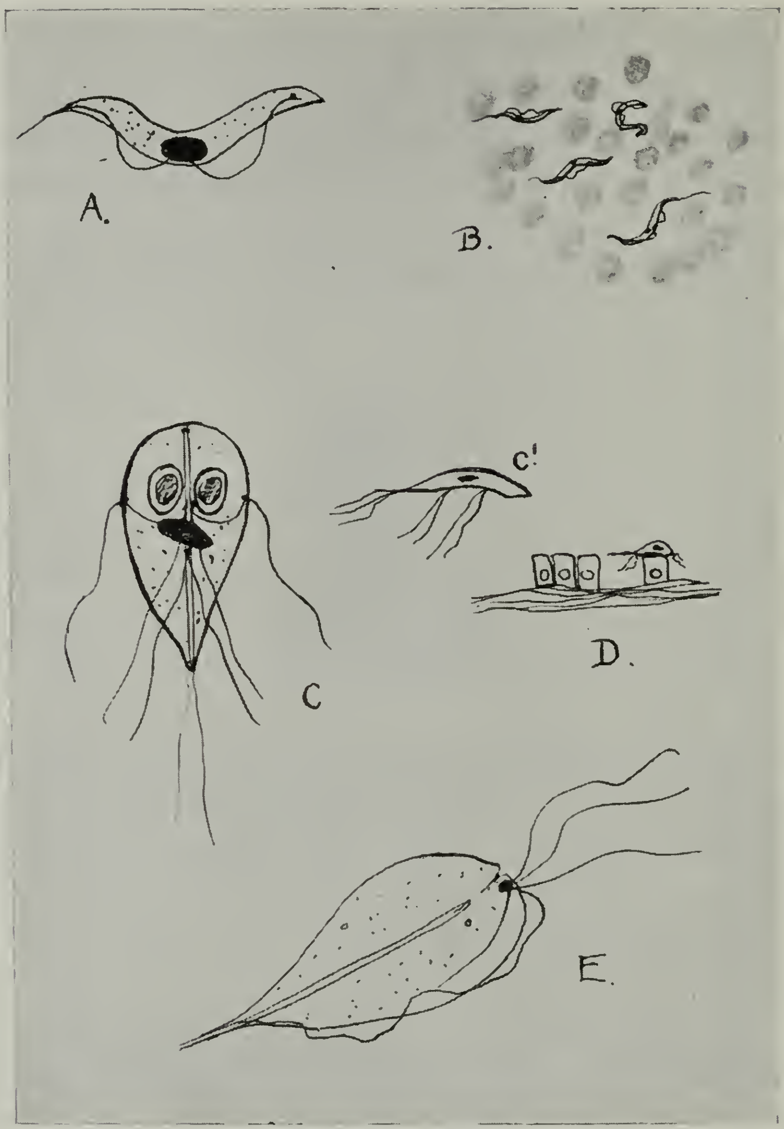


Fig. 102.—Various forms of protozoa. A, Trypanosome (enlarged about 2500 times). B, Trypanosomes in blood magnified 600 times. C, Giardia intestinalis (diagram). C′, Giardia (side view, showing concavity). D, Epithelial cells in intestine showing how Giardia attach themselves. E, Trichomonas hominis (diagram).

The Trypanosomes.—The *trypanosomes* are elongated and pointed organisms and have the appearance shown in Fig. 102. The most important species in human disease are those which cause *African sleeping sickness,* (*T. gambiense and T. rhodesiense*).

The trypanosomes live in the blood and are transmitted from person to person only by a biting fly, called the *tsetse fly.* The fly acts as an *intermediate host* and the trypanosomes undergo a portion of their development in its body.

Prevention of the disease depends on elimination of the tse-tse flies and certain wild animals which act as carriers. Drugs are not very effective and the infected person usually dies.

Plasmodium Vivax: Plasmodium Malariae: Plasmodium Falciparum.—Malaria has been discussed in Chapter XXVII. The names of the three types of malarial parasite are given above. P. vivax causes tertian, P. malariae, quartan, and P. falciparum, estivo-autumnal malaria.

Balantidium Coli.—This is a pear-shaped organism about the same size as Trichomonas hominis. It moves about by means of cilia protruding from its body at all points.

Balantidium coli is thought to cause mild intestinal disturbances, but its relation to any serious disease is doubtful. It is found in the feces and transmitted by them.

CHAPTER XXIX

YEASTS AND MOLDS

Yeasts and molds: relation to bacteria; importance—Yeasts: characteristics; pathogenic forms—Molds: characteristics; pathogenic molds.

Relation of Yeasts and Molds to Bacteria.—Up to this point we have been studying the very simplest plants and animals—the bacteria, which are unicellular plants, and a few single-celled animals, the protozoa. We now consider a group of plants, the yeasts and molds, which, although exceedingly simple in structure in comparison with the higher plants, are yet much more complicated than the bacteria. As we have seen in the discussion of protozoa, the bacteria are closely linked through this group to the animal kingdom. Through the yeasts and molds, they are related to the plant realm. In fact, from the standpoint of botanical classification, bacteria, yeasts and molds are considered as different groups in the great family of *fungi*. (Chapter I.)

From her nature study the nurse will doubtless recall that the fungi lack chlorophyll, the green pigment by means of which under the influence of sunlight, the higher plants build up their food substances from water and the carbon dioxide of the air. Plants which lack chlorophyll, as the bacteria, yeasts, molds, and other fungi, cannot as a rule live an independent existence, but are parasites on higher organisms which prepare their food for them in organic form.

Importance of Yeasts and Molds.—These lowly plants had great *historical* importance in the early development of bacteriology, because it was especially the investigation of the activities of yeasts in fermentation that led up to the first studies of bacteria. In 1837, Schwann, a botanist, showed that yeast cells were living things and that they had a causal relationship to fermentation, which had previously been thought of as of a purely chemical nature. As was said in Chapter II, Pasteur began his life work with the study of the fermentation of wine by yeasts, and proceeded from that to purely bacteriological researches. The specific relationship of micro-organisms to diseases was first proved in some of the diseases caused by molds and yeasts (favus and thrush in 1839; pityriasis versicolor in 1846).

Industrially, yeasts and some molds are of great importance. In this connection it is necessary only to mention the making of bread, wine, and beer. The characteristics of Roquefort and Camembert cheese are due to the growth in them of special molds.

In connection with the *diseases of plants, the lower animals, and man*, these fungi are also of importance. Molds are the cause of a considerable number of plant diseases which cause great economic loss, for example, chestnut blight, wheat rust, and white-pine blister. As causes of disease in man, yeasts and molds are of much less importance, comparatively, than bacteria. Nevertheless, they produce some human diseases, a few of which are very serious.

In connection with the medical aspects of molds, the nurse will recall from her study of materia medica that *ergot* (Fig. 108) is a destructive mold growing on rye.

From an agricultural standpoint, it is the cause of a grain disease.

Yeasts.—These are single-celled organisms (Fig. 103), 20–40 times as large as most cocci. Everyone is familiar with the baker's yeast cake, which is composed of countless numbers of these unicellular plants.

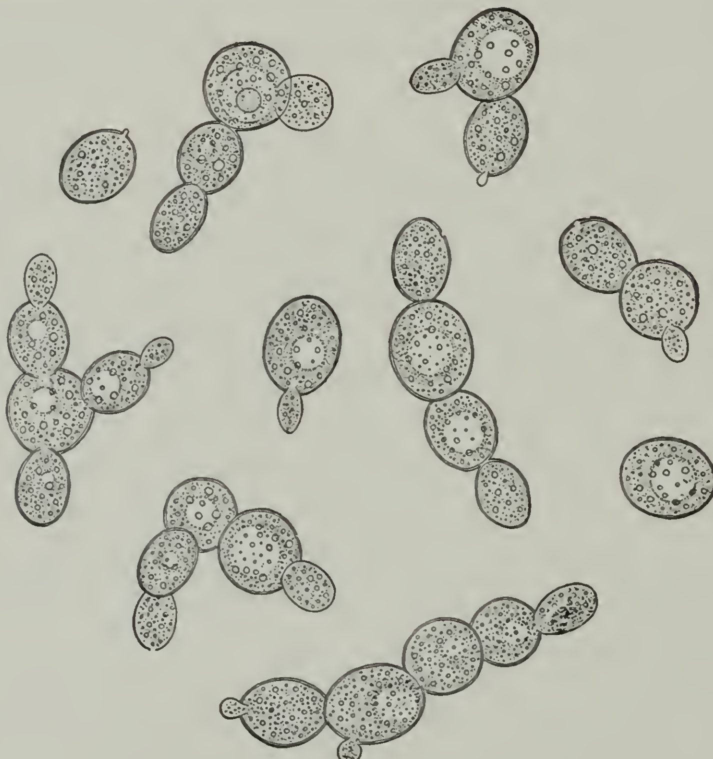


Fig. 103.—Yeast cells. Brewer's (top) yeast actively vegetating. The large internal vacuoles and the small fat-drops are shown, as are also buds in various stages of development, and the cell-wall. Nuclei not visible. (Highly magnified.) (Sedgwick and Wilson.)

The yeast plant resembles the bacteria in having a relatively simple structure, in being round or oval, and in its ready multiplication on ordinary food substances by the simple process of division.

Yeasts are especially characterized by their method of multiplication. When they multiply, they usually

divide into a large part and a small part called a "bud." The process is often called "budding." Yeasts form spores, much like bacteria.

Yeasts very readily use various kinds of sugar or starch as food. They give off enzymes which bring about the chemical changes in sugars and starches called *fermentation*, in which two products are commonly formed: alcohol and a gas called carbon dioxide.

Fig. 104.—Thrush, a pathogenic yeast. Unstained. (After Zettnow.)

Both of these are found in beer, new wine, and raising dough. The holes in bread are due to the gas bubbles. The foam on beer and the effervescence of champagne are also due to the carbon dioxide formed by the yeast.

There are various species of yeasts which produce different by-products during the process of fermentation. The use of *pure cultures* is therefore of great importance in industry, where differences in flavor and other qualities of the product depend on the particular species of yeast employed.

Pathogenic Yeasts.—A few yeasts cause disease in man. They are tabulated on p. 355. Most of the pathogenic yeasts differ greatly both culturally and morphologically from baker's yeast, especially when growing in the body tissues.

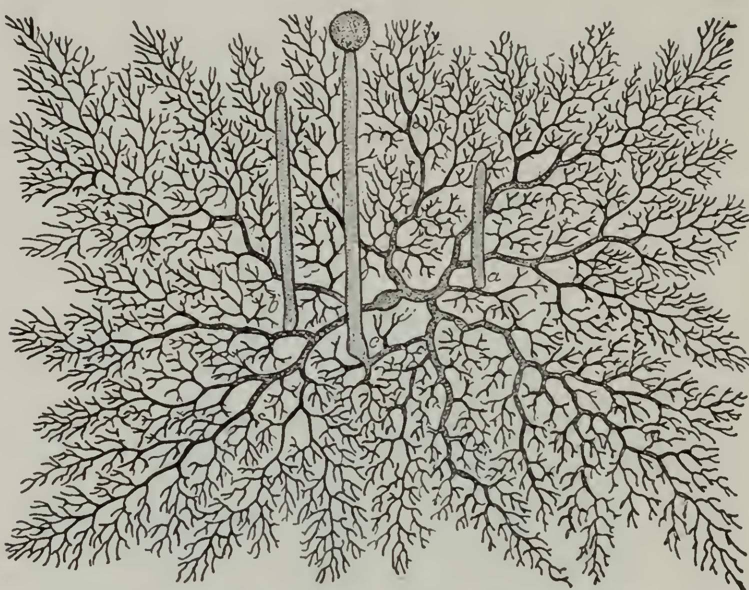


Fig. 105.—The common bread mold, showing branching filaments and spore capsules. (After Kny, from Tavel.)

Fig. 106.—The capsule of the bread mold filled with spores; its rupture and the scattering of the contents. (After Brefeld.)

Diseases Caused by Yeasts

Name of yeast.	Disease caused.	Mode of transmission (aside from directly coming into contact with the lesion).
Oïdium albicans also called *Monilia albicans.*	*Thrush,* (Fig. 104) a disease of the mouth in malnourished infants; associated with a membrane. *Sprue,* a tropical disease, characterized by an inflammation of the entire intestinal tract. Often fatal.	Unknown.
Cryptococcus......... Several species: *hominis gilchristi, Saccharomyces tumefaciens,* and others.	*Blastomycosis:* Ulcers on skin, or abscesses in bone and tissues of various parts of the body. Usually fatal.	Unknown.
Torula meningitidis...	*Meningitis:* Fatal.	Unknown.

Molds.—Everyone is familiar with the green, brown, black, or white molds often seen on stale bread, jars of jelly, or on rags which have lain in a damp place for a long time. If such material is examined with a magnifying glass, it will be seen to consist of a beautiful, almost fairy-like plant. Tiny threads penetrate into the substance on which it grows. The so-called "stems and branches," all are glistening and transparent. Each branch consists of many cells arranged end to end. The fruit (spores) is usually deeply colored and grows in great profusion. Each little colored ball is a spore or a mass of spores.

Typical molds (Fig. 105) are made up of cells joined in branching filaments forming a felt-like growth, the mycelium, from which the reproductive cells, the spores, develop. The spores are contained in capsules, which eventually burst (Fig. 106), freeing their contents. The

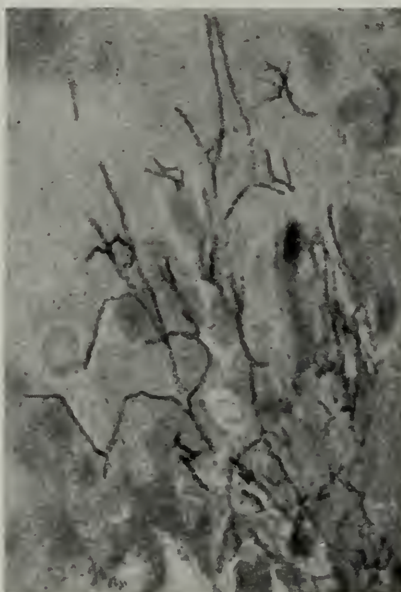


Fig. 107.—Actinomyces, one of a group of filamentous branching microörganisms which are regarded as occupying an intermediate position between the bacteria and the molds. The smear from the lesion shows branching filaments. Magnified 1000 times. Actinomycosis occurs in cattle and occasionally in man. (Wright and Brown.)

spores of molds are distributed, like bacterial spores, by the wind, and are always present in dust.

In molds we thus see the beginnings of *division of function* into vegetative cells, which provide for *nutrition*, and *reproductive* cells. This is one step higher in organization than the bacteria and protozoa, in which all the functions of the organism are carried on in the single cell.

There are organisms which show *transitions* in form and cultural characteristics *between the mycobacteria,* of which the tubercle bacillus is the most prominent representative, *and the molds.* The similarity of these higher

Fig. 108.—The mold ergot, showing on the left, filaments and spores. On the right, a head of rye with masses of the mold among the normal grains. (Courtesy of Purdue University Experiment Station.)

bacteria, as they are called, to the molds, is shown most clearly in the general appearance of the cultures and the branching forms of the individual cells (Fig. 107). The tubercle bacillus occasionally shows branching.

Molds are widely distributed in nature, most of them harmless saprophytes. Many live in the soil and take an active part in the decomposition of organic matter.

Pathogenic Molds.—A few species of mold cause disease in human beings. The majority of mold infections affect the skin and its appendages. A list of some of the molds, with the disease caused by each, is

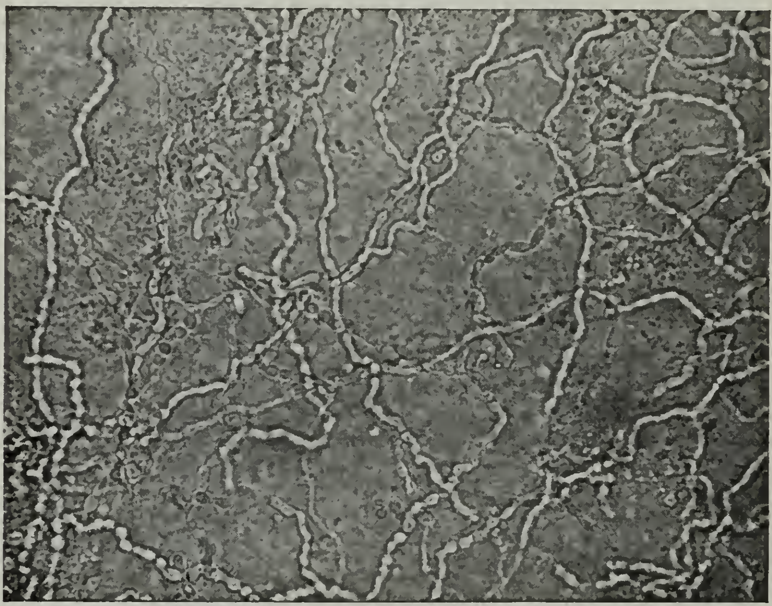


Fig. 109.—A fungus (*Actinomyces* or *Trichophyton*) causing "ringworm" of feet, sometimes contracted in swimming pools, gymnasiums, etc. This slide shows material taken directly from the foot; magnified 350 times. (Courtesy of Miss Rhoda W. Benham.)

appended. The mode of transmission of mold diseases is rather obscure. Actual contact with skin lesions caused by molds may be sufficient, especially if there are abrasions in the skin.

Favus and *sporothricosis* may extend deep into the body and fatal cases have been reported in each disease. The diseases caused by molds are very stubborn as a rule and often resist treatment for a long time.

Diseases Caused by Molds

Name of mold.	Disease caused.	Mode of transmission.
Microsporon furfur...	*Pityriasis:* Not a dangerous disease. Brownish-red spots.	Not definitely known. Often occurs on persons with delicate skin and in those who perspire freely and who are not overclean.
Achorion schönleinii..	*Favus:* A scalp disease resulting in baldness.	Not definitely known. Often thought to be carried by pet animals such as dogs or cats.
Trichophyton (various kinds).	"*Ring-worm*" (Tinea): Occurs on scalp, face, hands, and feet (Fig. 109).	Direct contact with the lesions. Often thought to be contracted from pet dogs, cats and horses.
Sporothrix...........	*Sporothricosis:* Invades tissues, producing lesions which resemble tuberculosis in some respects.	Pus from lesions contains the organisms.

CHAPTER XXX

THE COMMUNICABLE DISEASES AS PUBLIC HEALTH AND SOCIAL PROBLEMS[1]

The acute communicable diseases: immediate and later effects—Social conditions favoring infection—Principles of prevention and control: isolation; precautions continued during convalescence; discovery and control of missed cases and carriers; isolation of the well; immunization—The public health and social aspects of chronic infections—The various aspects of bacteriology.

The Effects of the Acute Communicable Diseases.—These diseases are important for both their immediate and their later effects. Acute infectious diseases, chief among which are diphtheria, scarlet fever, poliomyelitis, whooping cough, and pneumonia, are the most frequent causes of death in children between two and five years. The great loss of life among adults from pneumonia and the acute streptococcic infections may also be mentioned.

The *consequences* of the contagious diseases are often of greater importance than the diseases themselves. Even in children who recover completely, nutrition and growth are interfered with for some time. The weakened condition after an infectious disease, in either a child or an adult, may allow tuberculosis to get a start. The vital organs may be permanently damaged by these diseases in ways which seriously handicap the victim for life. The injury to the kidneys accompanying scarlet

[1] This discussion is extended in Morse's Public Health and Social Questions for Nurses. W. B. Saunders Co., 1932.

fever may be an important cause of nephritis in later life. The heart is damaged in many infectious diseases, especially diphtheria, acute rheumatic fever (Fig. 42) and streptococcic infections, and this may be the beginning of serious heart disease. Inflammation of the brain occasionally occurs in acute infectious diseases and may result in epilepsy, mental instability, or defect. Scarlet fever as a cause of deafness has been mentioned. Poliomyelitis (Fig. 87) ranks first among the causes of permanent crippling. These illustrations show that the prevention of the contagious diseases is one of the most important health problems.

Social Conditions Favoring Infection.—We may mention first *poverty*, which means a generally low standard of living, with insufficient food and clothing, often long hours of work under unhygienic conditions, with fatigue and exposure.

Even more important is *overcrowding*, which necessitates close personal association, with every opportunity for the spread of infection by contact. Where a large family lives in two rooms and takes boarders besides, where children sleep three or more in a bed, all wash with the same cloth and eat from the same dish, where all families in the house use the same toilet, the transmission of germs can scarcely be avoided. Bathing is infrequent, and there are all sorts of uncleanly and unhygienic habits. Overcrowding in schools, institutions, and "homes," also promotes the spread of infectious diseases.

Quite as important also are the *lack of intelligence, the ignorance and superstition* which hinder the adoption of modern ideas of hygiene and the carrying out of measures to prevent the spread of infections. Wherever

these conditions are found they all combine to favor the spread of infection.

Even in the beginning of her ward work, the nurse who takes a personal interest in her patients and does some independent thinking will gradually come to see the influence of social conditions on disease. She will realize them more fully in the out-patient department, especially if there is an opportunity for home visiting. A large part of the work of the public health nurse is concerned with improving the home conditions which tend to spread disease and with teaching the simple rules of personal hygiene.

Principles of Prevention and Control.—Certain points in regard to *prevention and control* apply to all infectious diseases.

The first is the *necessity of isolation* as soon as the first symptoms of any disease appear. Isolation is frequently begun too late. Every person, especially children, with a cold, a sore throat, or fever should be isolated until the diagnosis can be made. Isolation is even more urgent if a rash is present and in case of mild intestinal disturbances which may be forerunners of more severe disease.

There are *three degrees of isolation*, as practised when the patient remains at home: (*a*) *Strict isolation*, in which patient and nurse remain in a separate room, which no other person enters except the doctor, and from which nothing is taken without being properly disinfected.

(*b*) *Modified isolation*, which means that well members of the family or outside visitors do not come into contact with the patient, although they may enter the room. The excretions of the patient and everything

soiled by him are of course properly disinfected and disposed of.

(*c*) The lightest degree of isolation is placing upon the patient the *special restrictions* which are necessary to prevent him from infecting others, but aside from this, allowing him to mingle with the family and the public. This degree of control is sufficient in tuberculosis, gonorrhea and syphilis after the acute stage, and in the case of various carriers.

In most of the acute contagious diseases, health departments enforce a more or less strict isolation on the patient and members of the household, the length of the isolation period and the other regulations depending on the particular disease.

Second, *disinfection* and other precautions must be continued just as conscientiously during convalescence as during the height of the disease.

Third in importance are the *mild missed cases* of diseases. These explain the apparently mysterious origin of many known cases. The missed cases are just as infectious as the severe cases and, in fact, are even more dangerous, because the patient comes in contact with more people. Many of these cases are discovered by nurses in various kinds of public health work.

Fourth, the *discovery* and *control of carriers* is of equal importance with the isolation of the sick. At present, this applies particularly to diphtheria and typhoid infections. Carriers can be detected only by laboratory examination; that is, by isolating the causative organism (when it is known) by means of cultures from the excretion or secretion in which the organisms of the disease would be found.

Fifth is the importance of what may be called the *isolation of the well;* that is, preventing them from coming in contact with an infectious disease. This point deserves attention. It applies particularly to children. In general, the younger the child, the more severe the infectious disease is likely to be. As we have seen, most of the deaths from measles, diphtheria, scarlet fever, and whooping cough occur in young children. It is therefore of the greatest advantage to a child if he can be kept away from all infectious diseases until he is at least five years old.

In the case of adults, also, all unnecessary contact with communicable diseases, even such cases as pneumonia, should be discouraged. This would tend to lessen the number of carriers as well as of actual cases.

The importance of shielding from infections old people, babies, and persons with chronic diseases, has been mentioned. An organism which causes only a mild infection in a vigorous person may give rise to a fatal disease in an old person, an invalid, or a baby.

Sixth, the development of an efficient method of *preventive immunization, i. e.,* the production of active immunity, is the goal of research into the prevention and cure of any communicable disease; and immunization, in conjunction with the care of the clinical case and the discovery and control of carriers, will bring the final victory over communicable diseases. Vaccination against smallpox is the most brilliant example of the suppression of a disease through immunization. Immunization of a part of the rising generation to diphtheria is already a reality. As for typhoid fever, some immediate danger is usually necessary, except among certain groups, to make people avail themselves of the protection which is within easy reach of everyone.

The general immunization of a population against any disease begins with the special groups who are most exposed to it; as nurses and doctors; those who are specially susceptible, like children; or among whom the disease would be particularly liable to spread, as in armies and institutions.

The Public Health and Social Aspects of Chronic Infections.—To realize the immense importance of this subject, the student has only to call to mind the effects of the most common chronic infections—tuberculosis, syphilis, gonorrhea, and malaria. We have already touched on some of these problems in the discussion of each disease. Here we shall mention certain aspects common to various chronic infections.

In the first place, it is very probable that low-grade chronic infections are an important cause of the *degenerative diseases*. This is a convenient term for a number of conditions which occur in middle and later life and have as a common characteristic that they are a premature wearing-out of the body. The most frequent of them are arteriosclerosis (hardening of the arteries), and certain common types of heart disease and nephritis. The degenerative diseases are among the greatest problems of medicine and public health and probably the greatest cause of disability, invalidism, and death.

The infections which have the most important relation to degenerative conditions are those caused by the streptococcus and included under the term *chronic septic conditions*, and *syphilis*. The infection in septic conditions may be located in various places. The tonsils and the roots of the teeth are favorite situations. These chronic infections may cause very slight or no symptoms, and may thus go on for years without attracting the person's attention or causing him suffi-

cient discomfort so that he is forced to have them remedied. The streptococci may be carried in small numbers from the original place of infection to the heart, arteries, and kidneys; or the organs may be damaged by continuous minute doses of poison formed by the organisms at the original site and carried in the blood stream. Late removal of persisting infections may not stop the changes which have been set up in the organs, and of course will not repair the injury already done. Damage to the heart, arteries, and kidneys progresses slowly but steadily, frequently long after the active infection has subsided, and a considerable number of years may pass before the consequences are apparent.

Any serious chronic infection has an important effect on the personality, but this phase of the subject is outside the province of bacteriology. Chronic infections result in a reduction of efficiency, more or less prolonged and pronounced. When many individuals in a community are partially incapacitated by a chronic infection, for instance malaria, the total effect is marked. A high type of civilization is impossible in malarious regions.

In injury to childhood, the chronic infections rank with the acute. One need only mention the cases of congenital syphilis and the children infected through family contact with tuberculosis.

The chronic infections impose a tremendous burden on society. They involve a greater financial outlay on the part of both the individual and the community than do the acute infections. The community bears the economic burden of the clinics, hospitals, nurses, and social workers necessitated by the various chronic infectious diseases. It also suffers danger from the man with brain syphilis who may wreck his train, his

business, or the finances of an institution, or kill a fancied enemy. The marital unhappiness caused by syphilis and gonorrhea is incalculable. Then there are all the public health and social problems which center around prostitution. Chronic illness ranks with unemployment as the two greatest causes of poverty which necessitates financial relief from public or private sources, and chronic infections and the diseases resulting from them make up a large proportion of chronic sickness.

The Various Aspects of Bacteriology.—The subject of this book is the scientific aspect of bacteriology. The science, however, is not limited to the laboratory; it branches out into many fields and has applications to many phases of life. The laboratory is, however, the foundation and the starting point for all the various aspects of bacteriology. Some of these applications are so extensive that they constitute specialties in themselves, for example bacteriology in relation to plant physiology and pathology. The bacteriological problems and methods of public health differ considerably from those of clinical medicine; those of veterinary medicine are different from those of human medicine.

In the bacteriological laboratory the student gets the ideals and methods which apply to all kinds of scientific work; and in addition, an indispensable foundation of special knowledge and technic, as well as actual contact with bacteriological material. From there she goes on to the applications of bacteriology in nursing, clinical and preventive medicine, public health, and social problems. Although these various aspects are somewhat specialized, they are not disconnected. Bacteriology is a thread which is woven into many phases of life.

APPENDIX

(A) THE COLLECTION OF SPECIMENS FOR BACTERIOLOGICAL EXAMINATIONS

Labeling—Swabs—Throat cultures—Sputum—Urine—Feces—Blood: culture; Wassermann reaction; agglutination tests; films—Fluid from the peritoneal and pleural cavities—Cerebrospinal fluid.

As the nurse sometimes collects specimens for bacteriological examination, it is important for her to know the correct methods. If she does not take the specimen herself, she may make the preparations for it; and in any case she should have an intelligent interest in the procedure.

The value of a specimen may depend entirely on the care with which it is taken. In the first place, poorly taken specimens waste the bacteriologist's time. In the second place, it may be impossible to make any diagnosis on such a specimen, or a wrong diagnosis may be made. If it is worth while to take a specimen at all, it is worth while to take it carefully and correctly.

Labeling.—The first consideration about a specimen is the *label.* Each label should have on it *the patient's name, the date, the place from which the specimen is taken* (throat, cervix, abscess, etc.), and the ward or service. If the label is pasted on, a rubber band wrapped around it is an additional precaution.

If specimens are taken from a number of patients at the same time, each one must be labeled as soon as it is taken. Finish entirely with one specimen before going on to the next. Do not let the specimen out of the hand

until the label is complete. If there is the *faintest suspicion* that two specimens have been mixed, both must be discarded and a new start made. A mix-up in throat cultures or Wassermann tubes might have serious consequences.

Specimens should be sent to the laboratory at the *earliest possible moment.* This prevents the specimen from drying, bacteria from dying off, makes possible an earlier report, and is a convenience to the bacteriologist in planning his work.

Swabs.—Material for bacteriological examination is often conveniently collected on *swabs.* These are put in some container and the whole sterilized before use. (Fig. 16.) Swabs are used for a considerable variety of specimens; for example, throat cultures, pus, smears from the cervix, eyes, ulcers, etc. For use in the operating room, culture-tubes are wrapped in a cotton cover, like other surgical supplies, and autoclaved. The outside of the tube is thus sterile and can be handled by the surgeon at the operating table.

The nurse is often required to use the swab to inoculate culture media. This may be slanted in a tube, or flat in a petri plate. The tip of the swab, after it has touched the desired lesion or infected place, is passed back and forth over the surface of the medium with very gentle pressure, making a series of zig-zag paths on the surface (Figs. 16 and 61). The important point in taking a swab culture is to touch the swab *only on the spot from which the culture is desired,* and nowhere else, and to send it *immediately* to the laboratory.

Throat Cultures.—These should be taken only with a clear view of the throat, in a good light, and using a tongue-depressor. Material to be examined for diph-

theria bacilli should be taken directly from the tonsil, or from any white or inflamed spots in the throat. The same is true of cultures for scarlet fever or other infections of the throat.

Cultures from the nasopharynx are made particularly for meningococci by means of a special swab (Fig. 49). Meningococci, when present, are located high up behind the soft palate.

Sputum.—If the examination is to be of value, the specimen must be obtained in the proper way. The sputum collected by patients in the ordinary sputum cup consists to a large extent of material from the mouth and throat, mucus, saliva, and bits of food. To collect a sputum specimen correctly, a sterile container should be obtained from the laboratory. If the patient is able, he should brush his teeth and rinse the mouth thoroughly with water. The sputum should be collected directly after a cough and sent immediately to the laboratory. Sputum is obtained from infants by swabbing the throat.

It is often advantageous to make "cough plates" which have been mentioned previously in connection with whooping cough. A petri plate containing medium suitable for the growth of the organism desired is held before the mouth of the patient when he coughs. The spray of sputum raised by the coughing inoculates the plate. The plate is immediately covered and placed in the incubator.

Health departments supply outfits for collecting sputum for examination *for tubercle bacilli only.* These consist of wide-mouthed bottles containing a little disinfectant. An antiseptic can be used in this case only because in examining for tubercle bacilli, one does

not make a culture, but hunts for them with the microscope in a stained smear made from the sputum. *If a culture is to be made* from sputum or any other material, it is obvious that a *disinfectant must not be added.*

Urine.—Specimens of urine for *bacteriological* examination are of value only when they are collected with extreme care. There are immense numbers of bacteria on the skin and mucous membrane of the genitalia, and unless the mouth of the urethra is cleansed thoroughly, the culture is sure to be contaminated. The urine is collected by catheterization, and the usual technic for that must be scrupulously carried out. The first part of the urine is allowed to run off, in order to wash out any bacteria which may be present in the urethra, and the last cubic centimeters are collected in a *sterile* test-tube. Specimens for *chemical* and microscopic examination need not be sterile.

Specimens from the kidneys are collected by catheterization of the ureters, which is a surgical procedure. The important point about the specimens, from the nurse's standpoint, is to be *absolutely sure* that the tubes from the right and left kidneys are correctly designated.

Feces.—Bacteriological examination of the feces is undertaken most often for typhoid and dysentery bacilli, or the eggs of animal parasites, such as hookworms or tapeworms. Stools for bacteriological examination should be *fresh.* If blood or pus is present, it should be selected for the culture.

Carriers of both typhoid and dysentery bacilli are found by making cultures from the feces. The finding of typhoid bacilli in the stools or urine of carriers is difficult, as the organisms may be absent at times, and

Fig. 110.—Methods for securing blood by puncture of a vein. The middle figure shows distention of the veins of the arm about the elbow. The needle is entered by a quick upward thrust. Practically any prominent and firm vein may be used. The upper left-hand figure shows collection of blood in a test-tube. Usually 10 cc. or more are easily collected before clotting occurs. The lower right-hand figure shows collection of blood in a Keidel vacuum tube. (From Kolmer, "Infection, Immunity, and Biologic Therapy.")

are usually present in comparatively small numbers. Many health departments provide a special outfit for stool cultures from suspected typhoid cases or carriers.

This consists of a medium containing bile and an aniline dye, brilliant green. The medium is tubed in 5 cc.

Fig. 111.—The Keidel tube for collecting blood specimens. This consists of a 5 cc. bulb (*a*), drawn out into a capillary tip and sealed after a vacuum has been created by heating. A short piece of rubber tubing (*b*) fits over the capillary tip and connects it with the needle. The tubing and needle are protected by a glass tube (*c*) plugged with cotton. The entire apparatus is sterilized in a hot-air oven. To obtain a specimen of blood, the glass tube is removed, the needle inserted in a vein (Fig. 110), and the capillary tip of the bulb crushed with a hemostat through the tubing. The blood then flows into the bulb to replace the vacuum.

amounts and sealed with a rubber stopper. To regulate the amount of feces added, a sterile swab is sent with each tube. The bile and brilliant green are favorable

to the growth of the typhoid bacillus and unfavorable to other bacteria, so that in some cases the bacilli may be found after the tube has been incubated for two, three, and even four days, when none have been found on the first day.

Blood. 1. *Cultures.*—Bacteria are present in the circulating blood in various diseases. In septicemia, streptococci are the organisms most often found. Pneumococci often enter the blood in pneumonia. In typhoid fever, typhoid bacilli are present in the blood in the early stage of the disease. Septicemia is always a serious condition. The diagnosis is made by cultivating the bacteria in the blood. The blood is taken from the large vein at the bend of the elbow. The skin over the vein is prepared by painting with iodine. A bandage is wound tightly around the upper arm in order to cause the veins to stand out prominently (Fig. 110). The pressure should be sufficient to close the veins but not the arteries. About 10 cc. of blood is removed with a syringe.

The vacuum tube (Fig. 111) invented by Dr. Keidel of the Johns Hopkins Hospital, is often used instead of a syringe for withdrawing a number of cubic centimeters of blood.

The bacteriologist may bring his tubes to the bedside and inoculate them on the spot, before the blood has clotted. If the blood must be carried some distance to the laboratory before it can be inoculated, it is mixed with a sterile solution of sodium citrate which prevents it from clotting. Ox-bile is often used in media for blood cultures in typhoid fever.

2. *Blood for a Wassermann test* is obtained in the same way as for a blood culture, except that, instead of

using a syringe, the blood is allowed to flow through a large needle directly into a test-tube. The tube containing the blood should be set upright and *not moved until the blood has clotted.* Health departments

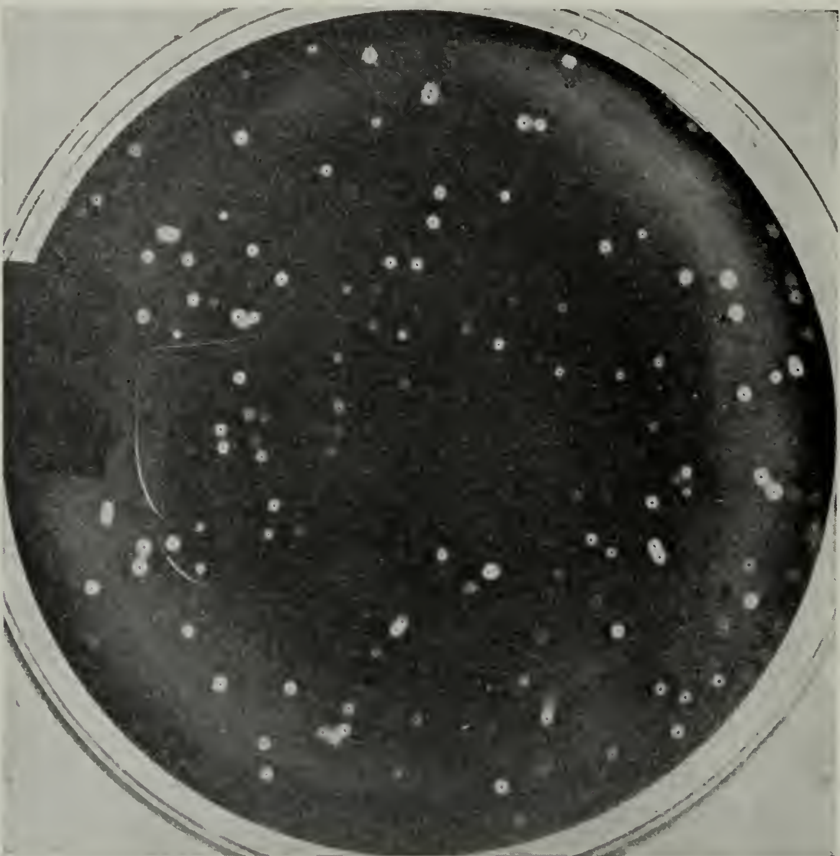


Fig. 112.—A blood culture from a case of septicemia. The petri plate shows colonies of hemolytic streptococcus. The hemolysis produces a "halo" around each colony. Compare with Fig. 40. (From Hiss, Zinsser and Russell, "Text-Book of Bacteriology." D. Appleton & Co., Publishers.)

furnish, for collecting blood for Wassermann reactions, outfits consisting of a sterile corked test-tube and a sterile needle.

In *infants*, blood for the Wassermann reaction is taken from the longitudinal sinus, a great vein which

lies immediately under the anterior fontanel. The blood is withdrawn in a syringe after shaving and cleansing the skin.

3. *For the Widal and other agglutination tests,* only a few drops of blood are needed. Unless these are taken from the syringe when blood is drawn for a Wassermann or blood culture, it is necessary to puncture the finger or the lobe of the ear. The latter has the advantage

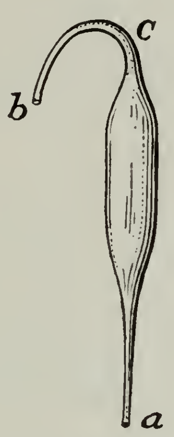


Fig. 113.—The Wright tube or capsule for collecting small amounts of blood. A piece of ordinary glass tubing is drawn out in the flame to capillary fineness at *a* and *b*, and bent at *c*. It is broken at *a* and *b*. The end *b* is applied to a drop of blood on the finger or ear. The blood rises in the tube by capillary action. The ends of the tube are sealed in the flame. These tubes can be made in quantity in any laboratory.

that the patient cannot watch the procedure. The best place to puncture the finger is through the thin skin at the bottom of the nail. Before the puncture, the finger or ear should be wiped with cotton moistened in alcohol, and afterward, touched with iodine.

A small crook-necked tube (Fig. 113), invented by Sir Almroth Wright, is used in many hospitals to collect a few drops of blood.

4. *Blood for films to be examined microscopically* is taken from the finger or ear, and spread in a thin uniform layer on an absolutely clean slide. The slides are washed with soap and water, rinsed, put through concentrated acetic acid, rinsed with distilled water, then washed with alcohol, and dried with lens paper.

To make a film, the drop of blood is put near one end of the slide. The short edge of a second slide is then held over the drop at an angle. When the edge of the second slide is brought down on the drop, the blood spreads between it and the surface of the first slide.

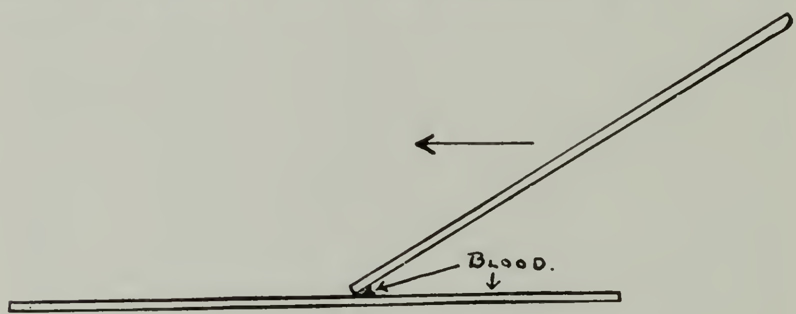


Fig. 114.—Glass slides arranged for making a film of blood for microscopic examination. We are looking at the slides edgewise. The arrow shows how to move the tilted slide.

Now, with the edge of the tilted slide in contact with the surface of the first one, push the tilted slide away from the drop. A thin, even film of blood will be left behind. Some practice is necessary to make a smooth film. (Fig. 114.) The slide is allowed to dry in the air, away from dust, and is then stained.

Fluid from the Peritoneal and Pleural Cavities.—This is either withdrawn in a syringe or allowed to run from the puncture needle directly into sterile test-tubes or centrifuge-tubes. If tuberculosis is suspected, some of the fluid is inoculated into the peritoneum of a guinea pig.

Cerebrospinal Fluid.—This is examined for the diagnosis of the different kinds of meningitis (Fig. 48), for acute poliomyelitis, and for syphilis of the nervous system (Figs. 78 and 79). The fluid is obtained by *lumbar puncture* and is allowed to run from the needle directly into sterile test-tubes or centrifuge-tubes.

In acute meningitis caused by the meningococcus, pneumococcus, streptococcus, or other organisms, the appearance of the fluid may range from slight cloudiness to thick pus. Smears and cultures are made to determine what bacteria are present.

Cerebrospinal fluid may be clear and yet be very abnormal. In poliomyelitis and syphilis it is usually clear, while in tuberculous meningitis it is either clear or slightly cloudy. If there is a suspicion of tuberculosis, the fluid is injected into a guinea pig.

In a clear or cloudy fluid the number of white cells is counted, using the same technic as in leucocyte counts of the blood, and the relative proportions of the different varieties are determined from a smear of the sediment. The amount of albumin and globulin is determined by precipitating it chemically. Both the number of cells and the amount of protein may be much increased although the fluid remains clear. In addition, a special test called the colloidal test is performed. This is of special value in differentiating paresis from other forms of neurosyphilis.

Cultures are not made on fluids from suspected cases of syphilis, but a Wassermann or Kahn test is carried out.

(B) EXPERIMENTS AND DEMONSTRATIONS

Note to instructor. Note to students. Exercises 1–20.

The following exercises are intended merely as suggestions. It is manifestly impossible to outline a course of exercises which will fulfill the needs of every course.

Note to Instructor

The instructor must adapt the exercises here outlined to his needs. Many of the experiments will prove too elaborate, some will be unavailable because of lack of material. Many experiments which will fit in better with the course being given, will probably suggest themselves to the resourceful instructor.

It is suggested that wherever possible the instructor demonstrate the method by actually doing the thing first and then letting the students do it after him. This saves much talk and is much more effective than descriptions of methods. One can discuss what he is doing as he works. The students do the work much more quickly after seeing the thing done.

The order of work in the exercises is designed to follow the order in which the material is presented in the text.

Note to Students

Each student should provide herself with a notebook in which she should write up each experiment or demonstration according to a standard form. The following form is useful:

1. State the purpose of the experiment or demonstration.

2. List the materials used.

3. Give a brief description of what was done and the *reason* for each step.

4. Note the results of each experiment and tell why that result was obtained, or what conclusion you can draw from it.

Exercise 1

(*a*) Demonstrate the construction, use, and care of the compound microscope.

(*b*) Mix a bit of yeast cake with water, mount on a slide, examine with the high dry lens, and draw.

(*c*) Examine and draw a mount of a mold.

(*d*) Examine a hanging drop of a twenty-four hour old culture of B. subtilis in a hanging drop preparation.

(*e*) Rub a few drops of xylol along the margin of a rabbit's ear. Shave away the hair. Notch the marginal vein with a sharp scalpel and collect two or three cc. of the blood in a test tube. Allow to clot. "Ring" the clot and set in the refrigerator till next time.

(*f*) Make a film of blood from a student's ear or finger, stain with Wright's stain, and examine for different kinds of cells. (See appendix Fig. 114.)

Exercise 2

(*a*) Note clot and formation of serum in blood collected last time.

(*b*) For the study of putrefaction, put a piece of lettuce leaf and a bit of raw meat each into a test-tube of water. Incubate. Examine next time.

(*c*) The members of the class should coöperate in the following experiment: Pour 4 plates of agar. Expose one on a table while dusting with a dry duster. Expose another by touching it with the lips. Allow a roach (dipped in a culture of staphylococci) to run over the third plate. Lay a hair (from a head inclined to dandruff) on the fourth. Other experiments of this type will suggest themselves.

(*d*) Make streak cultures on blood-agar plates from the throats of some of the students. Demonstrate at this time the method of taking throat cultures properly.

(*e*) Fermentation: Fill 3 fermentation tubes ¾ full of starch suspension, flour suspension, and dextrose solution respectively. Add 1 cc. of yeast suspension to each tube. Place the tubes in a water bath at 37 C. Note time and amount of gas formation.

(*f*) Put a small amount of oatmeal or other cooked cereal in 3 sterile Petri dishes. Inoculate with B. prodigiosus. Incubate one dish, refrigerate the other, and hold the third at room temperature till next time.

Exercise 3

(*a*) Note results of cultures made last time.

(*b*) Demonstrate method of simple methylene-blue stain and let each student use it to stain a broth culture of staphylococci, streptococci, B. subtilis, and one of the vibrios.

(*c*) Repeat (*b*) using the Gram stain.

(*d*) Demonstrate method of examining for motility with hanging drop. (B. subtilis serves well.)

Exercise 4

(*a*) Working in groups of 3 or 4, prepare 500 cc. of extract broth and agar.

(*b*) Demonstrate method of adjusting reaction. Discuss use of indicators and of the various ingredients in the broth.

(*c*) Fish colonies from any available plates showing several kinds of colony.

(*d*) Inoculate a mouse intraperitoneally with pneumococci.

Exercise 5

(*a*) Note results of cultures fished, and of other experiments.

(*b*) Demonstrate method of autopsying mouse and make smears from peritoneal cavity. Cultures may also be made if desirable.

(*c*) Take four sterile packages, each containing a gauze sponge. Prepare a number of pieces of thread, 1 to 2 inches long; dip them in a broth culture of Bacillus subtilis, and allow to dry. Open the packages with aseptic technic and insert the threads. Bake Package I in the hot-air oven one hour at 150 C. Steam Package II in the Arnold sterilizer for half an hour. Autoclave Package III for twenty minutes under 15 pounds pressure. Use Package IV as a control.

At the end of sterilization put the threads into tubes of sterile broth. Examine at the next session and compare results.

(*d*) Perform the same experiment with Staphylococcus aureus or Bacillus prodigiosus.

(*e*) Dip the points of three pairs of forceps in a broth culture of Bacillus subtilis and allow to dry. Put each pair in a separate pan containing boiling water to which 1 per cent of sodium carbonate has been added. Boil the first pair thirty seconds, the second, one minute and the third, ten minutes. Make cultures at the end of sterilization.

(*f*) Repeat (*e*) with Staphylococcus aureus.

(*g*) Prepare a small jar of string beans for canning. Take water from the jar for culture. Steam the jar in an Arnold sterilizer for one hour on three successive days, making culture after each exposure.

(*h*) To demonstrate the power of steam under pressure, the instructor should perform the following experiment: Put a few drops of water in a test-tube and push a cork *lightly* into the mouth. Hold the test-tube in the flame a few seconds, using a holder. Keep the test-tube at arm's length and pointing away from the body. In what very common kinds of machinery is steam under pressure used?

(*i*) Demonstrate the action of a porcelain filter.

Exercise 6

(*a*) Note results of previous experiments.

(*b*) The probationers should be given the Schick test and those who are susceptible immunized. The class should see the method of making the test, observe the reactions systematically, and help with the immunizing injections.

(*c*) A similar procedure should be carried out with the Dick test and anti-scarlet fever immunization.

Exercise 7

(*a*) The class should become familiar with the sterile outfits for serum injection which are put up by manufacturers. Note the strength of the serum, license number, and return-date.

The students should be given special opportunities to observe any cases in which serum treatment is given, and they should hand in written reports, noting the dosage, methods of administration, and effect on the course of the disease.

(*b*) Inject a guinea pig with diphtheria toxin. Inject another pig with toxin, and follow with an injection of antitoxin sufficient to protect. Note results next time.

Exercise 8

(*a*) The instructor should show the method of making an autogenous vaccine.

(*b*) The class should observe any vaccine treatment given in the hospital.

(*c*) If practicable, the antityphoid inoculation of the probationers should be carried on in connection with this course. The students should help with the vaccinations and afterward observe the inoculated persons systematically, recording the symptoms, and taking the temperatures. The reports should be handed in.

All unvaccinated nurses should be vaccinated against smallpox. The class should assist in the vaccinations and observe the reactions systematically.

Exercise 9

(*a*) Each member of the class should make a culture from her fingers by passing them over a sterile agar plate. See also Exercise 2, *c*. (Save the plates for Exercise 12, *f*.)

(*b*) Each student should perform the following experiment: Take four sterile agar plates. (1) Breathe quietly a number of times on the surface of the first plate held 6 inches from the face. (2) Repeat the process while talking in an ordinary tone of voice. (3) Cough violently on the surface of the third plate held one foot in front of the mouth. (4) Repeat (3) using a mask. Incubate all plates and examine at the next meeting.

(*c*) The instructor should infect three dishes with Bacillus prodigiosus. The class should then coöperate in carrying out the following experiment: Prepare a panful of slightly soapy, lukewarm water (record temperature). Using a piece of gauze as a dishcloth, wash together in the pan the three infected dishes and three noninfected ones. Drain on paper toweling. Place 2 cc. of sterile broth in one infected and 2 cc. in one noninfected dish. Rinse by rotating the dishes. The instructor will then plate 1 cc. of the broth from each dish. Rinse one infected and one noninfected dish in a panful of the hottest water that will run from the tap (record the temperature). Drain, rinse, and plate as above. Boil the two remaining dishes for five minutes and proceed as above. Plate 1 cc. of water from the dishpan. Rinse the dishcloth in sterile water in a Petri dish. Plate 1 cc. of the water. Incubate the plates and examine at the next meeting.

(*d*) If flies are available, the experiment described in Exercise 2 (roach) should be repeated. Examine a fly with a hand lens.

(*e*) Each member of the class should observe herself for one-half day noting every opportunity for contact infection, both of herself and others, which she finds herself committing; for example, coughing into the open, licking postage stamps, omitting to wash hands, etc. Similarly, she should observe for one-half day the breaks in technic of those persons with whom she comes in contact. The reports should be handed in.

Exercise 10

(*a*) Note results of previous experiments.

(*b*) Each member of the class should make a culture from her lips by touching them to the surface of a sterile agar plate.

(*c*) Cultures from the fingers should be made in the following way: Pour 5 cc. of sterile broth into a sterile Petri dish. Rinse the fingers thoroughly in this broth. Make agar plates of the broth undiluted and diluted $\frac{1}{10}$.

(*d*) Make a streak culture from the throat and one from the nose. Examine stained specimens from the swabs. In this connection the nurses should study illustrations, or better, anatomical models of the nasopharynx and of the interior of the nose.

(*e*) Collect several centimeters of saliva in a sterile tube. Make plates of it diluted $\frac{1}{10}$ and $\frac{1}{1000}$. Examine a stained slide and a hanging drop.

(*f*) Make plates of the following dilutions of feces: $\frac{1}{10}$, $\frac{1}{1000}$, $\frac{1}{1{,}000{,}000}$. Make a stained slide and a hanging drop of the $\frac{1}{1000}$ dilution. Draw one field from the stained specimen.

(*g*) Isolate the colon bacillus from one of the plates. Note the odor of the culture. Make a stained slide. (Use Endo or eosin-methylene-blue agar.)

(*h*) Stain smears of scrapings from the tongue and teeth.

Exercise 11

(*a*) Note results of previous experiments.

(*b*) The instructor should demonstrate the method of making a standard plate count of the bacteria in a sample of poor grade milk.

(*c*) Incubate a little milk in a tube until next time.

Exercises 12 and 13

(*a*) Make smears from the milk incubated last time. Look for streptococci.

(*b*) Demonstrate blood-agar plates of alpha and beta types of streptococci.

(*c*) Demonstrate agar or Loeffler's serum slants of Staphylococcus albus and Staphylococcus aureus.

(*d*) Demonstrate smears from cases of gonorrhea.

(*e*) Repeat Exercise 2, *d*. (Use blood-agar plates for streptococci.)

(*f*) Repeat Exercise 9, *a*.

(*g*) Disinfect the hands according to the method in use on the wards, and plate again.

Incubate the plates and compare them at the next session with those of Exercise 9, *a*.

(*h*) Utilize the cultures previously made from the hands and throats of members of the class for demonstration of Staphylococcus aureus and Streptococci.

(*i*) Get soiled dressings and specimens of pus from the wards and make smears.

(*j*) Examine an unstained specimen of pus with the high dry lens. Note the leucocytes. Make a stained slide; examine for bacteria and draw some leukocytes.

(*k*) Illustrate the stages of an acute infection by the temperature charts of a pneumonia or typhoid case, or of any other acute infectious diseases which may be available in the hospital.

(*l*) Show cultures of pneumococci and examine microscopically. If possible, a mouse should previously have been inoculated with scarlet fever sputum, or streptococci. This may be autopsied and plates streaked.

(*m*) Examine a stained slide of any mucopurulent sputum to demonstrate the general composition of sputum (leucocytes, mucus, and bacteria).

(*n*) If possible, show either fresh or Kaiserling specimens of lobar and bronchopneumonia.

(*o*) Show pictures or models of the Eustachian tube and middle ear to illustrate the pathway of infection from the throat to the ear.

Exercises 14 and 15

(*a*) Note results of previous experiments.

(*b*) Inoculate fermentation tubes of lactose and dextrose broth with B. typhosus, B. coli, B. dysenteriae, and one of the paratyphoid bacilli.

(*c*) Examine and make notes on cultures made in Exercise 12 or 13.

(*d*) After incubation of the fermentation tubes, note presence of acid and gas. How do you distinguish between B. typhosus and B. dysenteriae?

(*e*) Demonstrate the Widal test.

Exercise 16

(*a*) Demonstrate smears from animals dead of anthrax.

(*b*) Demonstrate smears of cultures of B. anthracis, showing spores.

(*c*) Demonstrate cultures of B. anthracis.

(*d*) Inoculate a guinea pig with tetanus toxin and another with toxin and antitoxin.

(*e*) Inoculate a tube of sterile milk, sealed with vaseline and containing a bit of peptone, with B. welchii.

Exercise 17

(*a*) Note cultures and inoculations made last time.

(*b*) Show a culture of the diphtheria bacillus and have the class examine stained specimens. If there are cases of diphtheria in the hospital, cultures from them should be utilized. Cultures should also be taken from the throats, noses, and hands of the nurses who have been caring for the patients.

(*c*) Inoculate several tubes of sterile milk (without litmus) with diphtheria bacilli. Incubate with a sterile control tube. Make cultures from the inoculated tubes; then have the students pasteurize the inoculated tubes by keeping them in the water-bath at 60 C. for thirty minutes. Cool rapidly in cold water and take a culture from each.

Exercise 18

(*a*) Show cultures of the tubercle bacillus.

(*b*) Obtain a positive sputum (from the laboratory of the Health Department if necessary), and demonstrate the method of staining. The class should examine the slides.

(*c*) Show Kaiserling specimens of tuberculosis of the lungs and other organs, or fresh material if available.

(*d*) If a guinea pig is to be inoculated with tuberculous material in the regular course of the laboratory work, or if an infected animal is to be autopsied, it should be demonstrated to the class.

Exercise 19

(*a*) Show stained specimens of the Spirochaeta pallida. Through co-operation with the genito-urinary department of the hospital, or a Board of Health clinic it may be practicable to demonstrate the living organisms with dark-field illumination. If possible show a culture of the Spirochaeta pallida.

(*b*) Demonstrate a Board of Health Wassermann outfit.

(*c*) If Wassermann and Kahn reactions are done in the hospital, the methods should be demonstrated, and positive and negative results shown. If the hospital does not do its Wassermanns, the demonstration may be made through co-operation with the nearest Health Department laboratory.

Exercise 20

(*a*) Show stained slides of malarial blood, and fresh specimens, if they should happen to be available.

(*b*) If the class is held at the right season, catch some mosquitoes with a chloroform bottle and examine with a hand lens. A chloroform bottle is prepared as follows: Prepare a cork disc so that it will wedge

in the bottom of a small wide-mouth bottle. Saturate the cork with chloroform. Invert the bottle over a resting mosquito.

(*c*) Trypanosomes may often be found in the blood of wild or white rats. These are easily stained with Wright's stain.

(*d*) Yeasts and molds may be demonstrated at this time also. Mount a piece of moldy bread under low power to show spores and hyphae.

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(C) GLOSSARY

Abortion.—Expulsion or departure of the young from the uterus of the mother before independent life has appeared in the young.

Abrasion.—Mechanical damage to the skin and underlying tissues, with breaking of the skin, as by a blow or scraping.

Agar.—A gelatine-like substance used for cultivating bacteria on its solid surface and also in its depths.

Alpha.—First letter of the Greek alphabet. Used to designate certain types of streptococci.

Alveoli.—Small hollow spaces, such as the sockets of the jaw which hold the roots of the teeth; or the air spaces in the lung.

Ampoules.—Small vials or tubes, usually of glass, commonly used to hold serum or vaccine.

Aneurysm.—A sac-like dilatation of a blood-vessel due to injury of the vessel wall. Often syphilitic.

Angina.—Sore throat. Any acute pain.

Aniline.—A type of dye or stain, generally spoken of as "coal-tar" dyes; made from a by-product in the manufacture of illuminating gas.

Anterior poliomyelitis.—Infantile paralysis.

Antibody.—A substance produced by the body to neutralize or destroy bacteria or their poisons, or any foreign protein. Their exact chemical nature is unknown.

Antidote.—A remedy to counteract the effects of a poison.

Antiseptic.—A substance used to prevent sepsis by killing or preventing the growth of disease-producing bacteria.

Antitoxic.—Possessing the property of neutralizing or destroying toxin. The term is usually applied to serum.

Arsphenamine.—A drug containing arsenic; used to treat syphilis. Tryparsamide belongs to the same group of drugs.

Ascitic fluid.—Serum-like fluid which collects in the peritoneal cavity in certain diseases, such as cardiac decompensation, cirrhosis of the liver, and some types of nephritis.

Asepsis.—Absence of living organisms which might produce infection. Usually accomplished by preventing access of bacteria to places or things previously sterilized.

Attenuated.—Weakened; of reduced virulence or infectivity.

Autolysis.—Destruction of cells by substances produced by the cells themselves.

Beta.—Second letter of the Greek alphabet. Used to designate certain types of streptococci.

Biological products.—Substances for diagnosis, prophylaxis, or therapy, produced by bacteriological or immunological processes.

Biology.—The study of the form, structure, and activities of living things.

Bovine.—Relating to cattle (Latin).

Brucellae.—Organisms of the undulant fever group.

Calcification.—Deposition of calcium salts in tissues.

Capillary (tube).—A glass tube drawn out in the flame to a very small (hair-like) diameter.

Carrier.—One who harbors the germs of a disease although not suffering from the disease himself.

Caseation.—The characteristic "cheesy" degeneration of tuberculous tissue.

Casein.—The chief protein of milk.

Coagulation.—Clotting or "setting."

Cell.—In biology, the smallest unit of living matter; the structural unit of all tissues and living things.

Centrifuge.—A machine for whirling tubes or flasks containing fluids. The tubes are held in metal cups at the edge of the wheel. When the machine revolves, the tubes stand out horizontally with the bottoms away from the center because of the "sling." Particles in the fluid are thrown out from the center and collect as sediment in the ends of the tubes.

Centrifuge tube.—A short glass tube with a pointed bottom for use in the centrifuge.

Cerebrospinal fluid.—The fluid surrounding the brain and spinal cord and found in the ventricles of the brain.

Certified (milk).—Guaranteed by a medical milk commission to have been produced under sanitary conditions.

Cervix.—The part of the uterus which projects into the vagina.

Chlorophyll.—The green coloring matter of plants.

Cilia.—Tiny hair-like projections from cells.

Coal-tar.—A by-product in the manufacture of illuminating gas.

Communicable (disease).—One capable of being transmitted from one person to another in the ordinary course of life.

Conjunctiva.—The membrane lining the eyelids and covering the anterior part of the eyeball.

Contagious.—Easily transmitted from person to person by contact.

Cubic centimeter.—The volume of a cube 1 centimeter (approximately ½ inch) on each edge.

Cytoplasm.—That part of the cell protoplasm which is neither nucleus, cell-wall, nor other well defined structure.

Death-rate.—The number of deaths occurring each year in proportion to the total population. Usually expressed as number per 100,000 of population.

Dementia.—Loss of intelligence.

Dextrose.—The sugar found in fruits, glucose; also formed by the decomposition of more complex sugars, for example, cane sugar.

Disinfectant.—A substance which kills pathogenic bacteria. The term is usually applied to chemicals.

Ectoderm.—The outermost of the layers of cells found early in the development of the embryo, from which the skin and its appendages, the brain, spinal cord, and parts of the eyes develop.

Edematous.—Swollen with excess fluid in the tissue spaces.

Element.—Those substances of which all other substances are composed and which, until recently, could not be divided into simpler substances.

Emanation.—A product or a form of energy given off by a radio-active substance.

Endocarditis.—Inflammation of the lining of the heart and especially of the valves.

Endotoxin.—A toxin which remains inside the living cell and is not excreted into the surrounding medium.

Enteritis.—Inflammation of the lining of the small intestine.

Enzyme.—A substance of unknown composition, secreted by a cell, which has the power of inducing chemical changes in certain substances.

Epidemic.—A communicable disease which affects unusually large numbers of persons in a given locality at the same time.

Exotoxin.—A toxin excreted by the living cell into the surrounding medium.

Exudate.—Fluid and cells present in tissues as the result of inflammation.

Fallopian tubes.—The tubes through which the egg cells pass from the ovary to the interior of the uterus.

Fetus.—The unborn child after the end of the third month of pregnancy.

Filament.—A delicate thread-like fiber.

Filterable.—Capable of passing through porcelain or other types of filter which hold back ordinary bacteria.

Flagella.—Delicate whip-like outgrowths by means of which bacteria move.

Flocs.—Clumps or flakes.

Focus—(plural foci). A central point of infection from which bacteria may be carried to other parts of the body, where, perhaps, they set up secondary foci.

Fontanel.—Any one of the unossified spots on the cranium of an infant.

Foreign protein.—A protein not already a part of the body.

Gangrene.—Death of tissue in masses, as distinguished from death of single cells or groups of cells; for example, gangrene of a limb or of the appendix. Usually due to lack of blood supply and often connected with infection, as in a bedsore.

Gastro-enteritis.—Inflammation of the stomach and small intestine.

Genus.—In the classification of animals or plants, a group embracing one or more species. It ranks next above a species and next below a subfamily.

Globulins.—Proteins which with albumins constitute the principal nitrogenous compounds of animal and plant tissues. Globulins differ from albumins in chemical composition, solubility, and precipitability.

Gram.—(1) A scientist who devised a method of staining bacteria. (2) A unit of weight equal to about ½ the weight of a ten cent piece.

Ground-water.—Water which is found in the soil at various distances below the surface.

Hemolysis.—Destruction of the red cells with the liberation of hemoglobin.

Hemolysin.—A substance which produces hemolysis.

Host.—One who harbors a parasite.

Hydrocele.—A collection of fluid, resembling ascitic fluid, in the sac surrounding the testicle.

Ileocolitis.—Inflammation of the lower part of the small intestine and the large bowel.

Immunity.—Resistance to any particular disease.

Inactivate.—To make inactive or harmless. In connection with serum, it means heating to 56 degrees centigrade for one-half hour, in order to destroy the complement in the serum.

Incineration.—Destruction by burning.

Incubate.—To maintain under suitable conditions for growth.

Incubation period (of a communicable disease).—The time elapsing between the date of infection and the appearance of symptoms.

Incubator.—A room or cabinet for maintaining a certain steady temperature.

Infant mortality.—Deaths of children under two years of age in relation to the total number born annually.

Infection.—(1) The communication of a disease from one living body to another. (2) A condition in which virulent bacteria or related organisms are growing in the living body.

Infectious.—Capable of causing infection.

Inflammation.—A response of the body tissues to injury. Inflammation involves dilatation of the small blood vessels; increased temperature at the site of the injury; pain; and collection of fluid and sometimes leucocytes, causing swelling.

Ingestion.—The act of taking food or drink.

Inoculate.—To transfer living microörganisms to artificial culture media or to an animal.

Intraspinal.—Within the spinal canal.

Ion.—An atom or group of atoms carrying an electric charge.

Lesion.—Any injury to tissue.

Leucocytosis.—An increase of the white corpuscles of the blood.

Lethargic (epidemic) **encephalitis.**—An inflammation of the central nervous system probably due to a filterable virus. "Sleeping sickness." No relationship to African sleeping sickness.

Lumbar puncture.—The process of passing a hollow needle between the bony parts of the spinal column into the spinal canal. Usually done for the purpose of drawing off spinal fluid for diagnostic examination or for the injection of therapeutic substances.

Macroscopic.—Visible with the unaided eye.

Marasmus.—Wasting of the body or tissues.

Medium (bacteriological).—Any substance used for the cultivation of bacteria.

Melitensis.—Latin for "belonging to Malta."

Metabolism.—All the energy-producing changes in a cell or organism.

Microörganism.—Any organism which cannot be seen with the naked eye but visible with the microscope.

Morphology.—Shape or form. The study of form or structure.

Mortality.—Death rate, usually from a single or specified cause; expressed as number of deaths per 100,000 population.

Mucopurulent.—Composed of, or containing visible quantities of mucus and pus.

Mucous membrane.—The lining or covering of various soft or internal parts of the body, such as the alimentary, respiratory, and genitourinary tracts. Such membranes contain cells which secrete mucus.

Multicellular.—Consisting of more than one cell.

Mycelium.—The thready felt-like growth characteristic of most molds.

Nasopharynx.—The upper portion of the back of the throat and nose which is hidden by the palate (Fig. 49).

Necrotic.—Dead and disintegrating.

Neurosyphilis.—Syphilis of the central nervous system.

Nomenclature.—System of naming.

Organic.—Substances containing carbon which are or have been part of living things. Inorganic: substances which have never been part of living organisms; mineral.

Oscillations.—Rapid to-and-fro movements.

Parasite.—An organism which attaches itself to, or invades another, living at the expense of, or to the detriment of the latter.

Parasitize.—To become a parasite of.

Paresis (literally muscular weakness).—A special type of inflammation of the brain caused by Treponema pallidum (Fig. 78). Dementia paralytica.

Parturition.—The process of childbirth.

Pathogenic.—Capable of producing disease.

Pathology.—The study of disease.

Peritonitis.—Inflammation of the lining of the abdominal cavity.

Petri plate.—A round glass dish with flat bottom, straight sides and a similar cover, which fits down over it.

Phagocyte.—Any cell which has the power of engulfing solid particles as do leucocytes.

Pigment.—Coloring matter.

Placenta.—The afterbirth.

Platelets.—Tiny, roughly starshaped (stellate) bodies floating in the blood. They are supposed to be concerned in the clotting of the blood. They are not cells but may be pieces of cells.

Preventive medicine.—Medical efforts to prevent disease in the individual and especially in the community.

Prognosis.—A judgment in advance concerning the probable outcome of a disease.

Prophylactic.—Preventive.

Protein.—The foundation material which composes the vital and living part of cells. Protein has a definite chemical structure which may remain unchanged for some time after the death of the cell.

Protoplasm.—Practically identical with protein but is alive.

Pseudopod.—A temporary protrusion, usually of an ameba, for purposes of movement.

Ptomaine.—A poison produced by the action of bacteria on proteins.

Public Health.—The aspects of health or disease which affect the community as a whole, or in which the community has an interest or a responsibility.

Puerperal.—Following childbirth.

Purulent.—Containing pus.

Pyogenic.—Causing the formation of pus.

Quarantine.—The isolation of infected persons or those suspected of being infected, from all communication with noninfected or unexposed persons.

Respiratory tract.—All the air passages concerned in breathing, from the nasal passages to the lungs.

Sanitation.—The science and art of maintaining a healthful environment.

Saprophytic.—Living only on dead matter; causing decay.

Scarify.—To make small superficial incisions.

Seepage.—Soaking through.

Septicemia.—Presence of pathogenic bacteria in the circulating blood.

Sepsis.—A state of infection.

Serological.—Concerned with, or based upon, studies of serum.

Serum.—Fluid portion of the blood after formation of the clot.

Species.—See Genus.

Specific.—Related to or affected by a single germ, toxin, or disease.

Spermatozoa.—The male reproductive cells.

Sterility.—(1) Incapability of producing young. (2) Freedom from living bacteria.

Suis.—Latin for "relating to hogs."

Suppuration.—Formation of pus.

Susceptible.—Liable to become affected by a disease.

Suspension.—A liquid containing minute particles of undissolved solid.

Tissue.—A group of body cells having the same function.

Toxigenic.—Producing toxin.

Toxin.—A poison formed by a living organism, which, when injected into the body of an animal, engenders antitoxin.

Traumatic.—Caused by an injury.

Trachoma.—An inflammatory disease of the eye, probably caused by an ultramicroscopic virus.

Tryparsamide.—See arsphenamine.

Ultramicroscopic.—Not visible with any available apparatus.

Undulant (undulant fever).—Fever recurring in relapses, or rising and falling at more or less regular intervals of days or weeks.

Unicellular.—Consisting of only one cell.

Vaginitis.—Inflammation of the vagina.

Vas-deferens.—The tube leading from the testicle to the urethra through which the sperm cells pass.

Venereal (diseases).—Those transmitted by sexual intercourse.

Veterinarian.—One skilled in the diseases of animals.

Virulence.—Ability to produce disease.

Virus.—A thing or substance causing transmissible disease. Usually thought of as invisible and filterable. May or may not be alive.

Viscous.—Thick, stringy, slimy, like mucus or cold molasses.

Wheal.—A raised edematous area on the skin such as may be produced by the "hives."

INDEX

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V